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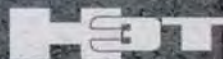
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Apollo 11 commander Neil Armstrong wore this space-suit when he became the first person to walk on the moon, July 20, 1969. Photographed by Christopher Griffith exclusively for PM at the Smithsonian Institute on March 12, 2009.

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NO

MARGIN

FOR

ERROR

The Untold Story of Apollo 11 To mark the 40th anniversary of the first moon landing, PM interviews flight controllers, engineers, scientists, astronauts and dozens of others who describe their roles, from liftoff to splashdown, in humankind's most audacious adventure. **Bonus pullout map:** The 17 critical events in the nearly flawless mission—and what could have happened if something had gone wrong.

84 Straight Outta

Aspen Who needs pavement for a great road trip? On this Colorado cruise in a restored Icon Toyota FJ40, we get dirt on our tires every day and a windshield full of scenery. **BY EZRA DYER**

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200-lb 1-kW Desk Two PM staffers find their inner Frankensteins and bring to life a monster computer. The glowing, bubbling, power-hungry creature proves to be awesome and unpredictable. **BY GLENN DERENE**

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Rumbling V8s, rear-drive power, raw speed—PM puts the comeback Camaro and four other muscle cars to the test. **BY LARRY WEBSTER**

ON THE COVER

Armstrong's A7L helmet on the Apollo 11 mission, photographed by Christopher Griffith exclusively for PM.

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Practice Deploying inventor Dean Kamen's two-wheeled wonder to improve military marksmanship. **Plus:** Powerful microwaves protect U.S. Air Force planes; engineering a championship Tour de France bike.

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The stimulus act earmarks billions for infrastructure projects, from power grids to water systems. PM tells Congress where the dough should go.

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Joe P. Hasler, Blaine McEvoy

EDITORIAL INTERNS

Kimberly Grzybala, Lindsey Pinkerton

Contributing Photographers & Illustrators:

Burcu Aysar, Tim Bower, Gordon Chapman/
Studio Catastrophic FX, Brad DeCecco, Dogo,
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TONY MARRO
PHILADELPHIA, PA

Thanks for a much-needed article. Highways today remove any need for caution on the part of the driver. With the current push to repair infrastructure, I hope engineers take these ideas to heart.

J WILLIAM HALFPENNY
WESTMONT, IL

America Plays Catch-Up

Less than 12 years after the Russians launched Sputnik, American Neil Armstrong was the first man to set foot on the moon, on July 20, 1969. Now, 40 years later, we have to rely on the technology of other countries ("The World's Space Fleet") to get into orbit. I wonder if this situation has anything to do with the U.S.'s dismal 26th-place ranking in world education.

ROBERT BARTLETT
OCALA, FL

Home Networking

Thanks for "Making the Most of Your Router." Browsing the Internet is no longer a painful test of patience—and the info about streaming Netflix movies through the Xbox 360 was a nice bonus.

TIM BEDET
BOSTON, MA

PM LETTERS

Calm Under Pressure

Thanks for the close-up glimpse of what it takes to be part of the Coast Guard helicopter rescue team ("Masters of Rescue," April '09). In life-or-death situations, it is often not just the physical and technical skills that matter, but as the author points out, the ability to make quick decisions, communicate clearly and remain focused and calm under harrowing circumstances. Coming from a town of sailors, I, for one, am grateful for the Coast Guard.

GEORGIA DALY
ANNAPOLIS, MD

Driving on the Edge

Thanks for the very interesting article, "Safety Through Danger?" Learning to drive on gravel and ice-covered roads taught me how to push the

ISSUE

04/09

Readers responded to Coast Guard rescue training, safe driving, space vehicles and router tips.

limits and to recover control—or end up in the ditch. Sacramento, Calif., is reworking a few suburban intersections into circles—a lot of complaints, but I'm looking forward to the results.

JOHN ROLLISON
CARMICHAEL, CA

Your article about safe driving in extraordinary conditions was interesting, but I don't think simulating danger is the best way to force people to drive more safely. Authorities should make the driving test mandatory every three years and increase speed limits by 5 mph. This will weed out the worst

what do you think?

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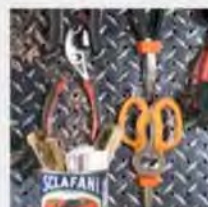
THE RACE FOR SPACE DOMINANCE

Iran launches a satellite, India gives the go-ahead for manned space missions, China scrambles to get to the moon, and NASA continues to work on Orion, lunar rovers and outposts on other planets. The 21st-century race for space dominance is underway, and **POPULAR MECHANICS** is there to cover it all—satellite launches, manned missions, space debris and more. popularmechanics.com/futurespace



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Tech Watch

Segway Target Practice

THESE ROLLING ROBOTS ARE JUST SMART ENOUGH TO BE SHOT BY MARKSMEN-IN-TRAINING.

BY JOE PAPPALARDO

Take a Bow

When the target is hit, the dummy stops and falls backwards so the shooter knows he scored a hit. Later analysis shows where the round entered.

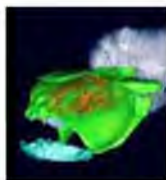
Who's a Tough Guy?

The mannequin is made of a durable plastic that can withstand hundreds of high-caliber shots.

Go Ahead and Shoot

The Segway is plated with high-strength steel and tested against 7.62-mm full-metal-jacket ammo.

→ The Segway may not have revolutionized human transportation as its boosters hoped, but Australian company Marathon Robotics has found a novel use for the two-wheeled vehicle: providing targets for military shooters by outfitting Segways with dummy torsos. The targets have onboard software that allows a group of them to head for cover. Each Segway is outfitted with a GPS and a laser navigation tool, and its base is armored to withstand errant shots. "When the shooter fires, the first one to get hit sends a message over Ethernet to the others so they scatter," says Alexei Makarenko, director of the firm. The Australian military began using the system to train snipers in 2008; Marathon started marketing to the U.S. this year.



SECRETS OF A FOSSILIZED FISH BRAIN

✦ French and American scientists using a particle accelerator to examine a 300-million-year-old fish skull were shocked to discover a fossilized brain inside, the oldest soft tissue of an animal brain ever discovered. Researchers were able to scan previously unseen nerve structures of the extinct fish.



New Tubes for Next-Generation Subs

A smarter way to bend metal is at the heart of Britain's new Astute class nuclear-powered attack submarines. Engineers developed an all-electric pipe-bender that can make parts from a single length of tubing. This allows complex pipe parts to be quickly manufactured to fit perfectly into the tight spaces available in subs and eliminates time-consuming and expensive X-ray and crack-detection tests required of welded joints. The first Astute sub will be delivered to the Royal Navy by BAE Systems sometime this year.

FINDING EARTH'S LOST MOUNTAINS

✦ An international team of scientists has mapped the Gamburtsev province of the Antarctic, the location of the last unexplored mountain range on the planet. The peaks and valleys are comparable to the European Alps, but their existence remained uncertain because they're buried under 2.5 miles of ice. The team used seismic sensors on the ice and seaplanes equipped with radar to survey the mountains.

NEWSBRIEFS

Reports From the Edge of Science

Compiled by Alex Hutchinson

Bent Blades for Quiet Helos

✦ A Defense Department program aims to develop "on-the-fly morphing rotor technology" for helicopters that would reduce vibration by 90 percent, making them more quiet and increasing their payload and range. Each rotor blade cuts through the turbulent air left by the blade in front of it, which causes a vibration; the new system uses piezoelectric blades that can rapidly change shape when an electric field is applied. Wind-tunnel tests show that pulsing electricity into the morphing rotor blades helps cancel out the vibration, cutting noise in half.

HOW TO MELT A DIAMOND

✦ Smashing projectiles into 1.9-carat targets, researchers at Sandia National Laboratories in New Mexico have determined the pressures at which diamond turns into liquid carbon. Scientists in California will use the results in 2010 when they shoot diamonds with lasers to research nuclear fusion.

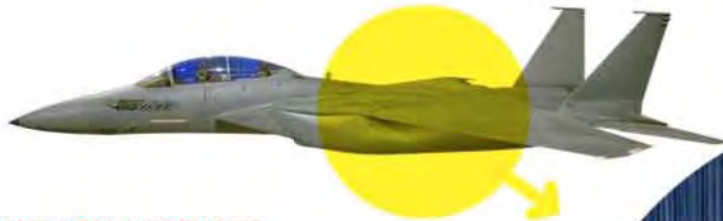


Bone Machine

✦ A team at Massachusetts General Hospital succeeded in growing a human thumb bone using a 3D printer. The machine places layers of biodegradable scaffolding, which is injected with stem cells. The scaffold is implanted under the skin of a mouse for six weeks, during which time human bone cells grow to replace the scaffolding, creating a copy of the thumb bone. The next hurdle is to ensure that blood vessels will connect to the replacement when it is implanted.



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STEALTH ON A BUDGET

The venerable F-15 gets an overhaul for 21st-century combat—and foreign customers. **BY JOE PAPPALARDO**

+ Achieving air superiority is harder than it used to be. Networks of powerful new radars and smarter missiles make warplanes, including the internationally renowned F-15 fighter, vulnerable to ground-based threats. In a bid to market the airplane to nations that can't

afford next-generation stealth warplanes—like the F-22 Raptor and F-35 Lightning II, built by rival Lockheed Martin—Boeing earlier this year unveiled the Silent Eagle, an F-15 with stealth features. Aeronautical engineers covered the aircraft with radar-absorbing material and redesigned the fuel tanks so that weapons can be

stored next to them inside the airplane, reducing its radar profile. The \$100 million airplane has an advanced radar system and canted vertical tails that provide extra lift. Boeing plans to shoot a missile from a flying prototype by 2010.



How the Silent Eagle strikes:

Small doors open and internally stored missiles swing into their firing positions.

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Science for Cyclists

PROFESSIONAL BIKE RACE TEAMS TURN HIGH-TECH TO MOD THEIR RIDES FOR THE TOUR DE FRANCE. BY PHAEDRA HISE

➔ **The design and materials of** Tour de France bicycles have more in common with airplanes than the Huffy a kid rides to the park. "We optimize every single aspect of the bike," says Jim Felt, founder of Felt Bicycles, which outfits professional cyclists around the world. Rider David Zabriskie (right) works with Felt and his team, Garmin-Slipstream, to keep his 16-pound bike studded with innovations. "A lot of guys don't like changing," Zabriskie says. "But for me, getting the new stuff makes me believe I'm going to go a lot faster." It's hard to argue with the results: Zabriskie holds the record for the quickest time trial in the history of the Tour de France, averaging 33.9 mph over 11.8 miles. Time trials are staggered throughout the Tour. Riders who do well shave valuable seconds from their current times.



GEARS

Gear manufacturers are incorporating high-tech materials like carbon fiber and exotic alloys in their gearsets to make them lighter. Zabriskie's Shimano gears are titanium.

HANDLEBARS

Zabriskie's time-trial bike (above) doesn't yet have new electronic shifting, but his road bike soon will. A button-activated solenoid triggers the derailleur to shift gears. Multiple shifting buttons can be placed anywhere on the handlebars.

FRAME

New ways to layer carbon fiber give riders stiffer bikes, which allows more of the rider's energy to be transferred to the wheels. The team uses software to tweak frame designs before costly testing in a wind tunnel starts.

WATER BOTTLE

New aerodynamic water bottles make the bike faster by acting as fairings that reduce drag on the back wheel. In addition, new bike frames feature a seat tube with a cutout to further smooth airflow.

REAR BRAKES

Pro bike manufacturers mount rear brakes down toward the bottom bracket to declutter the frame. Front brakes are being moved inside or behind the bike's front fork.

WHEELS

This solid-core rear wheel, built by Zipp Speed Weaponry, is parabolic to improve airflow. The surface of the carbon-laminate rim on the rear wheel is dimpled. As with a golf ball, the dimples help to cut through the wind and decrease drag.

THE PENTAGON'S CYBORG BUGS

Living insects are being hard-wired for future search-and-rescue missions.

➔ **Insects are still way ahead** of flying machines when it comes to relative range, speed, maneuverability and efficiency. That's why DARPA, the military's advanced research agency, has spent \$12 million since 2006 to fund groups researching ways to control the flight of living bugs. Three of the groups have performed successful experiments implanting minicircuits during the pupal stage of metamorphosis. When the insect emerges in adult form, the control chip is incorporated. This year a team led by the University of California-Berkeley used electrodes in a giant flower beetle's muscles and optical lobes to control its flight. The end goal: Stud the insects with cameras and sensors. — ALEX HUTCHINSON



The giant flower beetle (right) has a battery and microcontroller attached to its back with beeswax.



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THE GREAT PARTICLE HUNT RESUMES

Scientists restart the search for a fleeting bit of matter that could redefine our understanding of physics.

by Alex Hutchinson

+ The world's largest particle accelerator, the Large Hadron Collider, is expected to restart in September, a year after an accident halted work. When experiments resume, so will the hunt for the Higgs boson, known as the "God particle." Within a 17-mile tunnel, which runs along the French-Swiss

border, protons smash together at nearly the speed of light, forming new particles, which themselves decay into a shower of other particles. With as many as 600 million such collisions occurring each second, the search for prized rarities like the Higgs boson involves spotting the needle in an endlessly refilling ocean of hay. But the prize is worth the effort. The Higgs is the only particle predicted by the Standard Model of physics that has yet to be observed. The theory states that many elementary particles are only granted mass when they move through something called the Higgs field. Detecting the Higgs boson would be evidence that this field exists; not finding it could mean humanity's understanding of the basic laws of physics is flawed.

Particles emerging from the collisions within the LHC are tracked with this 6000-ton detector.



PM INTERVIEW
WEILL CORNELL MEDICAL CENTER
DOCTOR, DEATH RESEARCHER

Sam Parnia

HOW ARE THE HUMAN BRAIN AND MIND CONNECTED? TO FIND ANSWERS, A RESEARCHER IS CONDUCTING THE LARGEST-EVER MEDICAL STUDY INTO NEAR-DEATH EXPERIENCES TO ANSWER A PHILOSOPHICAL QUESTION: IS HUMAN CONSCIOUSNESS REALLY A PRODUCT OF OUR BRAINS? *By Amber Angelle*



Near-infrared scanners can track brain function at the point of death. Blue areas are not getting enough oxygen.

- Q** Your Awareness During Resuscitation study is gathering data on the experiences of heart attack patients between death and resuscitation. What are you trying to find out?
- A** Studies have shown that 10 to 20 percent of patients who are resuscitated report some kind of cognitive process during cardiac arrest. [During cardiac arrest a victim loses blood pressure; with no oxygen reaching the brain, patients die within minutes.] The big question is how can you have thought processes—or, for that matter, an out-of-body experience—when your brain isn't working?
- Q** How do you use brain scanners to gather clinical data on what might be going on in a dying person's mind?
- A** Currently we monitor a patient's electroencephalograph (EEG), which measures the brain's electrical activity, but we have very little idea of how well we're managing to get blood into the brain. The In-Vivo Optical Spectroscopy system (above) tells us how much oxygen is in the blood that is getting into the brain during resuscitation. If we can show that patients who report cognitive processes had oxygen levels of less than 15 percent during resuscitation, we will have support for the idea that the mind and consciousness are actually working when the brain is shut down. When we're presented with extreme circumstances and the brain doesn't function like normal you suddenly see that, perhaps, the mind itself is very subtle, immeasurable on any scan.
- Q** Do people say that you are investigating the paranormal?
- A** If a patient has an experience when they are dying I don't see why that is considered paranormal. The mind and the brain are interrelated. If I stick a pin in your hand, a brain scan will show blood-flow changes in areas of the brain as you feel pain and become upset. Also, when your mind is disordered it impacts the biochemical processes in your brain. But why should brain cells be able to generate a feeling of awareness? It's like saying the TV shows you watch are created by your TV set.

Parnia is a fellow in pulmonary and critical care medicine at Weill Cornell Medical Center in New York.



Playing H-O-R-S-E
with the kids

Quality time
in the garage

18 holes
with the guys

Movie night
with the Mrs

Recharge your T levels. What you do next is up to you.

Low energy. Moodiness. Low sex drive.

These may not be just normal signs of aging. They are a few of the symptoms experienced by many of the 13.8 million men aged 45 years or older with a common medical condition called low testosterone (Low T). On the bright side, Low T is easily treatable. AndroGel restores your T levels to normal range and may improve your symptoms over time.



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THERAPY FOR LOW T

TAKE CHARGE. VISIT WWW.ANDROGEL.COM AND ASK YOUR DOCTOR FOR A SIMPLE LOW T BLOOD TEST.

AndroGel is indicated for replacement therapy in adult males for conditions associated with a deficiency or absence of endogenous testosterone.

SAFETY INFORMATION:

AndroGel must not be used if you have known or suspected prostate cancer or breast cancer (a rare condition for men). AndroGel must not be used by women who are pregnant, may become pregnant, or breastfeeding, as testosterone may cause fetal harm.

The major risks of AndroGel include prostate enlargement, prostate cancer, and transfer of testosterone to others (including women and children). Transference can occur when vigorous skin-to-skin contact is made with the application site and can be minimized by washing your hands after application and covering the application site with clothing.

The most common adverse events reported are skin irritation

where gel is applied, breast development or tenderness, acne, prostate enlargement, changes in lab test results, and changes in urinary habits.

Remember, the information in this ad does not take the place of the advice you get from your doctor or other health care professional. Always talk with your doctor if you have questions about AndroGel.

Please see brief summary of Patient Information on next page.

You are encouraged to report side effects of prescription drugs to the FDA. Visit www.FDA.gov/medwatch or call 1-800-FDA-1088.

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www.AndroGel.com

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Brief Summary of Patient Information (For full Prescribing Information and Patient Information, refer to package insert.)

The following information about AndroGel® should not take the place of your doctor's orders or recommendations. Your doctor will tell you exactly what dose to take, how to safely take it, and when to take it. Make sure you understand the benefits and risks of AndroGel® before you use it. If you have any other questions about AndroGel® therapy, ask your doctor or pharmacist or visit www.androgel.com.

AndroGel (testosterone gel) 1% CII is available packaged with 2 x 75 g pumps (each pump dispenses 60 metered 1.25 g doses) or in a box of 30 packets with 2.5 g or 5 g gel.

This is a summary of the important information about AndroGel. For details, talk to your healthcare professional and refer to the package insert.

1. What Disease or Condition Does AndroGel Treat?

Your healthcare provider has prescribed this medication because your body does not produce enough testosterone. The medical term for this condition is hypogonadism.

2. How Should AndroGel (Pump or Packet) Be Applied?

It is important that you use AndroGel as prescribed by your healthcare professional. If you experience serious problems, contact your healthcare professional. Your healthcare professional will tell you how much AndroGel to use each day.

Men should apply gel to shaded areas (upper arm/shoulders, and/or abdomen) only.



Site(s) of Gel Application

- **AndroGel should be applied once daily at the same time each day** (preferably every morning) to clean, dry, healthy, intact skin of the shoulders, upper arms and/or abdomen. If you take a bath or shower in the morning, use AndroGel **after** your bath or shower.
- AndroGel **should not** be applied to the **penis or scrotum**, or to skin with open sores, wounds or irritation.
- **Wash your hands** with soap and water immediately **after application** to reduce the chance that the medication will spread from your hands to other people.
- Let AndroGel dry for a few minutes before you dress.
- **AndroGel is flammable until dry**; allow the gel to dry before smoking or going near an open flame.
- **Wait 5 to 6 hours** before showering or swimming. This will ensure that the greatest amount of AndroGel is absorbed into your system.

How to use the AndroGel pump?

It is important that you read and follow these directions on how to use the AndroGel Pump properly. Before using the pump for the first time, you must prime the AndroGel pump by fully depressing the pump three times and discarding the gel. The unused gel should be discarded in a manner to avoid accidental exposure or ingestion by household members or pets. Fully depress the pump the appropriate number of times to deliver the daily dose prescribed by your healthcare provider. The product may be delivered directly into the palm of your hand and then applied to the desired application sites, either one pump depression at a time or upon completion of all pump depressions required for the daily dose.

How to use the AndroGel packets?

Open one AndroGel aluminum foil packet by folding the top edge at the perforation and tearing completely across the packet along the perforation. Squeeze the contents into the palm of your hand. Squeeze from the bottom of the packet toward the top. If you like, you may squeeze a portion of the gel from the packet into the palm of your hand and apply to application site(s). Repeat until the entire contents of the packet have been applied.

3. What Should You Discuss With Your Healthcare Professional?

Before you start using AndroGel, tell your healthcare professional if you:

- Have prostate cancer or breast cancer.
- Have a known hypersensitivity to any of AndroGel's components, including individuals who are hypersensitive to testosterone that is chemically synthesized from soy.

4. What Other Drugs Should Not Be Used Together With AndroGel?

Tell your healthcare provider about all of the medicines you take, including prescription and non-prescription medicines, vitamins and herbal supplements. AndroGel can affect how your body handles other drugs. Changes in your dose or careful monitoring may be needed if you are taking any of the following medications:

- Insulin
- Corticosteroids
- Oral Anticoagulants

5. What Are The Side Effects And Risks?

Possible side effects of AndroGel to discuss with your healthcare professional include:

Most common: Skin irritation where gel is applied, breast development or tenderness, acne, prostate enlargement, changes in lab test results and changes in urinary habits.

Contact your healthcare professional if you experience any of the following adverse reactions:

- Too frequent or persistent erections of the penis.
- Any nausea, vomiting, changes in skin color or ankle swelling.
- Breathing disturbances, including those associated with sleep, or excessive daytime sleepiness.
- Changes in urinary habits such as increased urination at night, trouble starting your urine stream, passing urine many times during the day, having an urge that you have to go to the bathroom right away, having a urine accident, being unable to pass urine and weak urine flow.

The major risks of AndroGel include:

Prostate Disorders: Patients treated with testosterone may be at an increased risk for prostate enlargement, and prostate cancer. Talk to your healthcare provider for more information on risk factors and ways to monitor for prostate disorders.

Testosterone Transfer: Transfer of testosterone to others (including women and children) can occur when vigorous skin-to-skin contact is made with the application site. AndroGel must not be used by women, and exposure to the active ingredient testosterone in pregnancy can cause fetal harm. Notify your healthcare provider if your female partner develops changes in hair distribution, increases in acne or other signs of masculinity.

6. How Should AndroGel Be Stored?

Store at 25°C (77°F); excursions permitted to 15° to 30°C (59° to 86°F) [see USP Controlled Room Temperature]. Keep out of the reach of children.

7. Is There Anything Else I Need To Know When Using AndroGel?

Your healthcare professional has prescribed AndroGel to meet your specific needs; never share your AndroGel with anyone. If you have any questions or concerns about your AndroGel treatment, ask your healthcare provider or pharmacist.

Revised: December 2007

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Marietta, GA 30062-2224

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Rev 08-2008 [500122/500127 Rev Dec 2007(1)]



**Time
Machine**
MARCH
1962

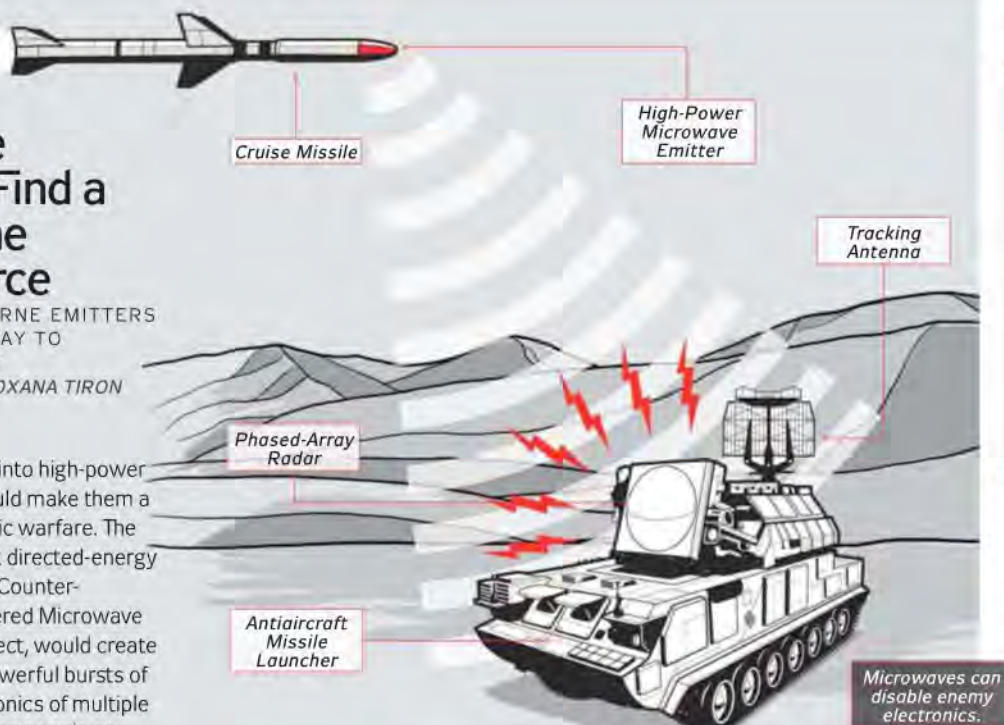


America's moonshot in 1969 stands as testament to great engineering and organization. However, all plans are subject to change. As early as 1962, **POPULAR MECHANICS** was analyzing NASA's concepts for the Apollo program. The launch vehicle was to be a "white-and-silver shaft jutting majestically 185 feet into the still-cool morning air," a description that paralleled the three-stage construction of the Saturn V rocket, but underestimated the eventual design by nearly 200 feet. NASA had considered launching several small rockets and linking their payloads in orbit—an idea that current NASA planners are mulling for a return to the moon by 2020—but chose one 363-foot Saturn V instead. (See "No Margin for Error," page 68.) — **ALLIE HAAKE**

Microwave Weapons Find a Home in the U.S. Air Force

HIGH-POWER AIRBORNE EMITTERS MAY BE AN IDEAL WAY TO NEUTRALIZE ENEMY ELECTRONICS. BY ROXANA TIRON

➔ **New research** into high-power microwaves could make them a crucial tool of electronic warfare. The U.S. Air Force's newest directed-energy weapon program, the Counter-Electronics High-Powered Microwave Advanced Missile Project, would create a weapon that fires powerful bursts of HPM, frying the electronics of multiple targets without harming people or other infrastructure. CHAMP's microwaves could be delivered from pods on airplanes, unmanned aerial vehicles or even retrievable cruise missiles programmed to safely land near their points of origin, says Doug Beason, a member of the Air Force's Science Advisory Board who has worked on directed-energy weapons. "You want to fly close to the target. You do not want to hit the target kinetically," Beason says. Hurdles to a usable system include miniaturizing the antennas and the power supply. According to Air Force documents, the winner of the \$40 million CHAMP contract, expected to be chosen this year, would have five years to demonstrate a working device.



Other USAF Directed-Energy Efforts

High-Energy Research and Applications Program

➔ The Air Force last year began the \$75 million HERA program to research aerial and ground-based HPM weapons. Researchers will focus on zappers that can generate peak power in the multi-gigawatt range and devices emitting on narrow- and wide-band microwave loads.

Active Electronically Scanned Array Radar

➔ AESA radars are made to scan the horizon for threats. However, if radio energy is concentrated on one spot, the radar can scramble the electronics of targets. U.S. warplanes currently carry the AESA radar, but officials do not speak publicly about their electronic warfare capabilities.

Active Denial System

➔ The ADS system, mounted on a Humvee, focuses a high-power, 95-GHz microwave beam at a target using a planar array antenna. The microwave energy penetrates up to 0.5 mm into human skin, producing an intolerable heating sensation but, designers say, no permanent damage. The Navy is looking into a similar system for ships.

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1 carat marquise-cut
DiamondAura® bail

3/8 ctw round
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5 carat pear-cut
DiamondAura® center

Set in .925 sterling silver

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Breaking the big-carat barrier. DiamondAura® has proven to be a magnificent lab creation since we first released it five years ago but, up until now we couldn't make a DiamondAura® pendant larger than 2 3/4 carats. Today we release the ultra-luxury, majestic lab-created DiamondAura pendant with stunning clarity, cut and color rarely seen. Our Pendant features a 5 carat, pear-cut DiamondAura that dangles from an 18" chain of the finest .925 sterling silver. The pear is topped with an impressive 1 carat marquise-cut DiamondAura bail.

The Four Cs. Our exclusive DiamondAura jewelry has splendid specifications: color, clarity, cut, and carat weight. We won't

COMPARE FOR YOURSELF AT 6 CARATS		
	Mined Flawless Diamond	DiamondAura® Compares to:
Hardness	Cuts Glass	Cuts Glass
Color	"D" Colorless	"D" Colorless
Clarity	"IF"	Clear
Dispersion/Fire	0.044	0.066
6 ctw necklace	\$200,000+	\$195

bore you with the details, but we've invested close to \$6 million in developing DiamondAura. The complex laboratory process involves rare minerals heated to an incredibly high temperature of nearly 5,000° F inside some very modern and expensive equipment. Using chemistry, we found a better way to match the fire and brilliance of a "D" flawless diamond at a much more reasonable cost.

Here's the plain truth: Times are tough, people are strapped and the bottom has dropped out of our economy. It doesn't matter if you're from Wall Street, Main Street or Rodeo Drive, everything has changed. If you have a house, a 401K or a bank account... you've taken a financial hit. But you still need to surprise her with something that will truly take her breath away.

Sound to good to be true? Let me explain: at Stauer we don't make money selling one piece of jewelry to you, we stay

in business by serving long term clients. Our data tells us that when you become a Stauer client, you'll be back.

Even a Recession has a silver lining. If you are not thrilled with the DiamondAura *French Pear Drop Pendant*, return it within 30 days for a refund of your purchase price. Our DiamondAura will last forever, but our **limited edition** will not. Call today to take advantage of this offer.

JEWELRY SPECS:

- 5 carat pear-cut center DiamondAura®
- 1 carat marquise-cut DiamondAura® bail
- Set in precious .925 sterling silver
- 18" princess-length chain of .925 tarnish-free sterling silver

French Pear Drop Pendant Necklace (6 ctw) only \$195

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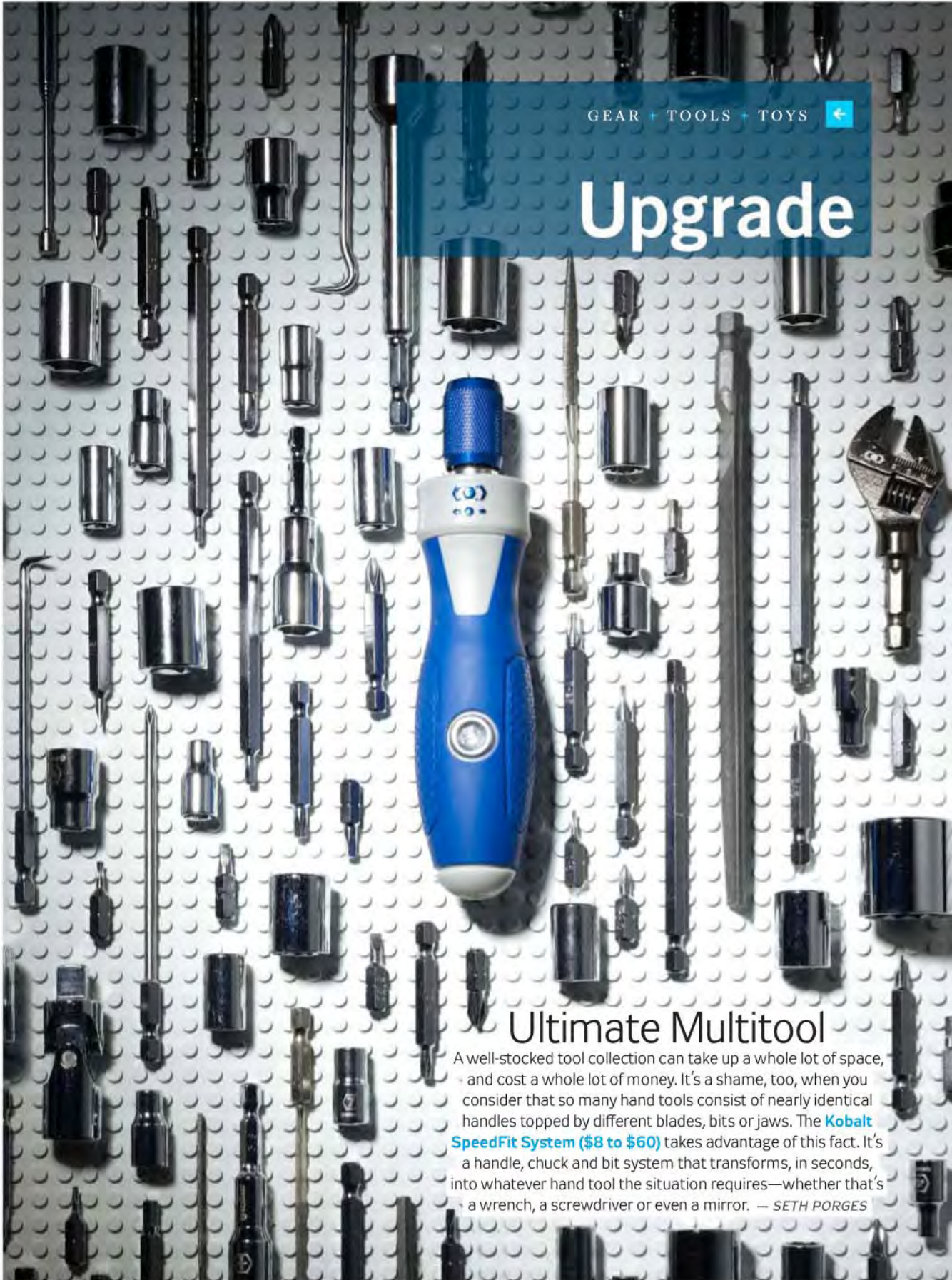
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Upgrade

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A well-stocked tool collection can take up a whole lot of space, and cost a whole lot of money. It's a shame, too, when you consider that so many hand tools consist of nearly identical handles topped by different blades, bits or jaws. The **Kobalt SpeedFit System (\$8 to \$60)** takes advantage of this fact. It's a handle, chuck and bit system that transforms, in seconds, into whatever hand tool the situation requires—whether that's a wrench, a screwdriver or even a mirror. — **SETH PORGES**

Step Up Your Grill Game

When it comes to grilling, it's easy to get started, but perfecting your technique can take a lifetime. Fortunately, some have done just that. We tracked down guys who've mastered grilling from the rub to the heat. Here's their expert advice on the tools and techniques you need to kick your grilling up a notch and maybe even surprise a few guests at your next BBQ bash. Think of it as your cookout cheat sheet. *BY SETH PORGES*



wood chip smokers' guide

Mesquite
Overwhelms anything but beef. Try combining it with other woods.

Hickory
Great when paired with pork and, to a lesser extent, poultry.

Oak
Highly versatile. Strong enough for beef, but won't overwhelm fish.

Cherry
Too light for beef, but great for poultry, seafood and veggies.

HEAVIEST

LIGHTEST

PM
grill
tips



To cook a steak well-done without drying it out, Pat Neely, co-host of Down Home With the Neelys, says: Take your almost-done steak off the burners and wrap it tightly in foil. Then, put the wrapped meat over indirect heat. It will continue to cook without charring or drying.

Always leave a third of the grill empty for wiggle room and a safe place to move food in a flare-up, says Steven Raichlen, host of Primal Grill and author of The Barbecue Bible.

the
PM
recipe



Grilled Pork Porterhouse Chops

created for PM
by Pat Neely

- Prepare grill for indirect grilling (crank one row of burners or move coals to one side).
- Melt 2 tablespoons unsalted butter with a couple of dashes of Worcestershire sauce.
- Season six double-cut pork porterhouse chops with salt and pepper, then brush with butter mixture.
- Rub grill grate lightly with vegetable oil. Cook chops on hottest spot on grill for 4 minutes per side (turning once), or until each side has grill marks.
- Move chops to cooler side of grill, brush with barbecue sauce, turn and brush other side.
- Cover chops with aluminum pan. Continue cooking until interior reaches 150 degrees (at least 10 minutes). Set aside for 5 minutes.
- Serve with BBQ sauce on the side.



Pat Neely
is the founder of
Neely's Bar-B-Que
restaurants and
co-host of the Food
Network's
Down Home
With the Neelys.



the ultimate setup



1. Grill Mat

A flexible concretized grill mat guards against grease drips.

2. Trash Can

A grill-side trash can saves trips indoors. Or use it to store wood chips.

3. Chimney Starter

The best way to light charcoals without taste-ruining lighter fluid. Heat the coals for 15 to 20 minutes before removing the chimney and putting in the grill.

4. Spatula

Forget those oversized hardware-store BBQ spatulas. The thinner, sharper and more flexible your spatula, the easier it is to perform surgical burger flips. Look for one that's stainless steel and at least 16 inches long.

5. Fork

Okay for quick meat moves, but jab sparingly or you'll leak juices. Look for a stainless-steel fork that's at least 16 inches long.

6. Grill Brush

The grill brush keeps your grate clean. Get a long, stiff wire brush.

7. Tongs

This is your primary food-moving tool. The best are stainless steel, spring-loaded and at least 16 inches long.

8. Knife Set

Cutting meat on a grill-side cutting board saves trips to the kitchen.

9. Infrared Thermometer

The easiest way to find out when the grill is hot enough. Point at the grate for instant and accurate readings.

10. Basting Brush

A regular pastry brush is perfect for basting. Opt for one at least 2 inches wide with natural bristles.

11. Instant-Read Thermometer

Quickly and accurately tells when meat is ready.

12. Table

An outdoor table or cart allows you to keep more tools nearby and serve dishes without shuttling back to the kitchen. Look for one with wheels, preferably made from easy-to-clean stainless steel.

13. Grill Mitts

Leather grill gloves offer heat and grease protection with maximum dexterity.

Steaks taste best if refrigerated until the last possible minute. To keep your cuts cool until they hit the grill, Raichlen suggests keeping an ice-pack-filled cooler grill-side.

How to grill fish without it getting stuck to the grate: Use tongs to grab a wad of paper towel, then dip it in oil and coat the grate. The flesh side of the fish is stickier, so start skin side down, and flip it just once. The tail cooks faster than the head, so keep it farther from the heat.

Quick Cam

We've seen high-speed cameras before, but none has made quite as much use of its burst abilities as the 9-megapixel, 20x-zooming **Sony Cyber-shot DSC-HX1 (\$500)**, which uses its 10-frames-per-second capability for a series of never-before-seen features. Hold the shutter and sweep the camera back and forth to automatically stitch high-speed photos into an up-to-224-degree panoramic shot. Or hold the camera steady to have it turn a series of almost-identical shots into a noise- and blur-free composite.



An early Super Soaker prototype from Lonnie Johnson's collection.

Look Back

THE SUPER SOAKER

Time was, if you needed serious firepower in a water fight, you had to reach for the

hose. That changed 20 years ago, when inventor and NASA scientist Lonnie Johnson came up with a way to use hand-pumped air pressure to power a water-gun blast. His Super Soaker would forever alter the way water wars are fought. While Johnson has since had a hand in (arguably) more important work, including a PM Breakthrough Award-winning method for generating electricity, he still looks back fondly on his water gun. "There are three inventions that I am really proud of," Johnson says. "The robot I built in high school, the circuitry for the Galileo spacecraft and the Super Soaker." To mark the gun's 20th anniversary, Hasbro is re-releasing the original blaster—the **Super Soaker 50 (\$15)**.

"I was working on a heat pump that used water as a working fluid and I made some jet pumps for it. I accidentally shot a stream of water across a bathroom where I was doing the experiment and thought to myself: This would make a great gun."

—Super Soaker inventor Lonnie Johnson on his eureka moment.

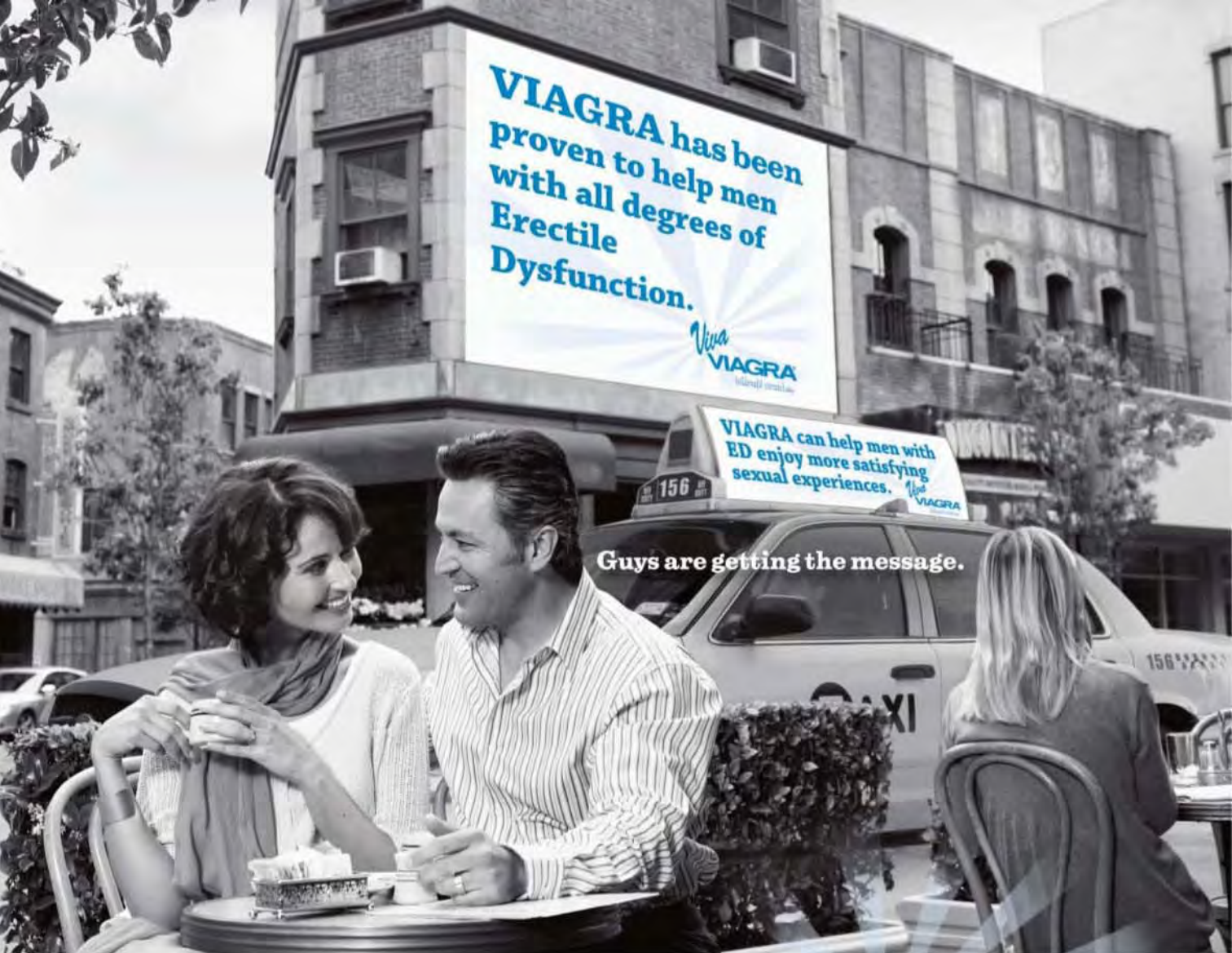


The re-released Super Soaker 50.



Sling Blade

If you want to chop wood on a camping trip, you could turn to a bulky, heavy axe. But the Gerber Kick Axe (\$65) is all the tool you need for accumulating campfire kindling. It weighs just over a pound and folds shut like a Swiss Army Knife. When closed, it's under 7 inches long, and compact enough for backpackers (it can even be stuffed into a pocket).



Guys are getting the message.

Men with Erectile Dysfunction (ED) are discovering that VIAGRA can help them get and keep harder erections, which can lead to more satisfying sexual experiences. Ready to get the message? *Read all about it at viagra.com.* Then ask your doctor if VIAGRA is right for you.

Viva
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(sildenafil citrate) tablets

VIAGRA is prescribed to treat erectile dysfunction. We know that no medicine is for everyone. Don't take VIAGRA if you take nitrates, often prescribed for chest pain, as this may cause a sudden unsafe drop in blood pressure.

Talk with your doctor first. Make sure your heart is healthy enough to have sex. If you have chest pain, nausea, or other discomforts during sex, seek medical help right away. As with any ED tablet, in the rare event of an erection lasting more than four hours, seek immediate medical help to avoid long-term injury.

In rare instances, men taking PDE5 inhibitors (oral erectile dysfunction medicines, including VIAGRA) reported a sudden decrease or loss of vision, or sudden decrease or loss of hearing. It is not possible to determine whether these events are related directly to these medicines or to other factors. If you experience any of these symptoms, stop taking PDE5 inhibitors, including VIAGRA, and call a doctor right away.

The most common side effects of VIAGRA are headache, facial flushing, and upset stomach. Less common are bluish or blurred vision, or being sensitive to light. These may occur for a brief time. VIAGRA does not protect against sexually transmitted diseases including HIV.

Please see Important Facts for VIAGRA on the following page or visit viagra.com for full prescribing information.
For free information, including questions to ask your doctor, call 1-888-4VIAGRA (1-888-484-2472).

*You are encouraged to report negative side effects of prescription drugs to the FDA.
Visit www.FDA.gov/medwatch or call 1-800-FDA-1088.*

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IMPORTANT FACTS

VIAGRA[®]
(sildenafil citrate) tablets

(vi-AG-rah)

IMPORTANT SAFETY INFORMATION ABOUT VIAGRA

Never take VIAGRA if you take any medicines with nitrates. This includes nitroglycerin. Your blood pressure could drop quickly. It could fall to an unsafe or life-threatening level.

ABOUT ERECTILE DYSFUNCTION (ED)

Erectile dysfunction means a man cannot get or keep an erection. Health problems, injury, or side effects of drugs may cause ED. The cause may not be known.

ABOUT VIAGRA

VIAGRA is used to treat ED in men. When you want to have sex, VIAGRA can help you get and keep an erection when you are sexually excited. You cannot get an erection just by taking the pill. Only your doctor can prescribe VIAGRA.

VIAGRA does not cure ED.

VIAGRA does not protect you or your partner from STDs (sexually transmitted diseases) or HIV. You will need to use a condom.

VIAGRA is not a hormone or an aphrodisiac.

WHO IS VIAGRA FOR?

Who should take VIAGRA?

Men who have ED and whose heart is healthy enough for sex.

Who should NOT take VIAGRA?

- If you ever take medicines with nitrates:
 - Medicines that treat chest pain (angina), such as nitroglycerin or isosorbide mononitrate or dinitrate
- If you use some street drugs, such as "poppers" (amyl nitrate or nitrite)
- If you are allergic to anything in the VIAGRA tablet.

BEFORE YOU START VIAGRA

Tell your doctor if you have or ever had:

- Heart attack, abnormal heartbeats, or stroke
- Heart problems, such as heart failure, chest pain, or aortic valve narrowing
- Low or high blood pressure
- Severe vision loss
- An eye condition called retinitis pigmentosa
- Kidney or liver problems
- Blood problems, such as sickle cell anemia or leukemia
- A deformed penis, Peyronie's disease, or an erection that lasted more than 4 hours
- Stomach ulcers or any kind of bleeding problems

Tell your doctor about all your medicines. Include over-the-counter medicines, vitamins, and herbal products. Tell your doctor if you take or use:

- Medicines called alpha-blockers to treat high blood pressure or prostate problems. Your blood pressure could suddenly get too low. You could get dizzy or faint. Your doctor may start you on a lower dose of VIAGRA.
- Medicines called protease inhibitors for HIV. Your doctor may prescribe a 25 mg dose. Your doctor may limit VIAGRA to 25 mg in a 48-hour period.
- Other methods to cause erections. These include pills, injections, implants, or pumps.

POSSIBLE SIDE EFFECTS OF VIAGRA

Side effects are mostly mild to moderate. They usually go away after a few hours. Some of these are more likely to happen with higher doses.

The most common side effects are:

- Headache
- Feeling flushed
- Upset stomach

Less common side effects are:

- Trouble telling blue and green apart or seeing a blue tinge on things
- Eyes being more sensitive to light
- Blurred vision

Rarely, a small number of men taking VIAGRA have reported these serious events:

- Having an erection that lasts more than 4 hours. If the erection is not treated right away, long-term loss of potency could occur.
- Sudden decrease or loss of sight in one or both eyes. We do not know if these events are caused by VIAGRA and medicines like it or caused by other factors. They may be caused by conditions like high blood pressure or diabetes. If you have sudden vision changes, stop using VIAGRA and all medicines like it. Call your doctor right away.
- Sudden decrease or loss of hearing. We do not know if these events are caused by VIAGRA and medicines like it or caused by other factors. If you have sudden hearing changes, stop using VIAGRA and all medicines like it. Call your doctor right away.
- Heart attack, stroke, irregular heartbeats, and death. We do not know whether these events are caused by VIAGRA or caused by other factors. Most of these happened in men who already had heart problems.

If you have any of these problems, stop VIAGRA. Call your doctor right away.

HOW TO TAKE VIAGRA

Do:

- Take VIAGRA only the way your doctor tells you. VIAGRA comes in 25 mg, 50 mg, and 100 mg tablets. Your doctor will tell you how much to take.
- If you are over 65 or have serious liver or kidney problems, your doctor may start you at the lowest dose (25 mg).
- Take VIAGRA about 1 hour before you want to have sex. VIAGRA starts to work in about 30 minutes when you are sexually excited. VIAGRA lasts up to 4 hours.

Don't:

- Do not take VIAGRA more than once a day.
- Do not take more VIAGRA than your doctor tells you. If you think you need more VIAGRA, talk with your doctor.
- Do not start or stop any other medicines before checking with your doctor.

NEED MORE INFORMATION?

- This is only a summary of important information. Ask your doctor or pharmacist for complete product information OR
- Go to www.viagra.com or call (888) 4-VIAGRA (484-2472).

Uninsured? Need help paying for Pfizer medicine? Pfizer has programs that can help. Call 1-866-706-2400 or visit www.PfizerHelpfulAnswers.com.



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 **helpful
answers**

Test Drive

LUGGAGE
YOU CAN
SIT ON

Seats can be in short supply at crowded airports. So there's something compelling about the carry-on-size **Züca Pro Luggage (\$285)**, which features a flat-top anodized aluminum frame that the manufacturer claims is tough enough to serve as a seat. To test it, we lugged it around town, on travels and to work. Our findings: The seat came in handy (it was far easier to get work done during layovers), but the sturdy structure comes at a price: It weighs 9.4 pounds, empty. And be careful when grabbing the top handle—its metal edges are a bit sharp.



Little Brother

If there's ever been an easier-to-hide home-security system, we haven't seen it. The **Avaak Vue Personal Video Network (\$300 for two cameras and base station)** uses tiny matchbox-size cameras that require no wires, period. The power comes from batteries, and the video is beamed to the Web, allowing users to check in live from any Internet-enabled PC, schedule recordings and download footage.



Who Ya Gonna Call?

If you lived through the '80s, you'll be excited about this one. ***Ghostbusters: The Video Game* (price varies by system)** picks up where the second movie left off, putting you in control of a proton-packing, marshmallow-melting 'Buster. The original cast is back, lending their voices, and the script is penned by the movies' scribes. The *Ghostbusters* trilogy is now complete.



Introducing the new FEIN family of dust extractors

Durable, compact and stable.

These great new dust extractors have an optimized shape with six wheels instead of four for added stability.

Incredibly quiet. At an average 60 decibels, they are far quieter than most other popular dust extractors.

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At 90 to 99 inches of water lift, FEIN dust extractors produce far greater suction than the competition.

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with an easy to read LED indicator that saves energy and reduces noise to an absolute minimum.

Powerful heavy-duty motor.

All FEIN dust extractors are designed for heavy-duty, continuous use with dual fan turbo cooling to extend motor life.

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SPORT SEDAN + PICKUP TRUCK



New Cars

Heavy Duty Hybrid

Diesels are the de facto option for saving fuel at the highest end of the pickup capability scale, but for light-duty trucks, the Chevy Silverado Hybrid offers the most frugal solution. We traveled deep into the heart of Texas—land of the pickup—to find out if these new trucks have the capability and efficiency we crave. The hybrid system is the same as the one in GM's SUVs and generates a total of 332 hp and 367 lb-ft of torque. The 6.0-liter V8 can also operate as a V4 under light load conditions. A 4WD Silverado Hybrid is rated at 20 mpg city and highway, so with a 26-gallon tank it has a range of 470 miles. We loaded a 2WD Hybrid with 800 pounds of sandbags and hitched it to a 5200-pound boat. There seemed to be plenty of torque to move the load and we averaged 14 mpg—not bad considering the work. —JOHN STEWART

2009 Chevy
Silverado Hybrid

Base Price: \$38,995

++ pm test driven



INSIDE
Honda Fury
Yamaha FZ6R
Porsche Cayenne S Hybrid
Infiniti G37 Convertible
Jaguar XFR
Mercedes-Benz E550
Aston Martin DBS



PM TEST
DRIVEN

→ Chevy Silverado Hybrid | **Honda Fury** | **Yamaha FZ6R** | Porsche Cayenne S Hybrid |
Infiniti G37 Convertible | Jaguar XFR | Mercedes-Benz E550 | Aston Martin DBS X

1 2010 Honda Fury

Easy Rider

Most people think of choppers as long and low customs, cobbled together in small shops by a dedicated group of talented, tattooed fabricators. But the Fury is a Honda, so it injects high levels of reliability into the equation too. The 1312-cc bike captures chopper styling but the ride is quiet and smooth—perhaps too much so for ironmen in pudding-bowl helmets. The staggered shotgun pipes are muted, yet deliver a faithful “potato-potato” beat with a baritone timbre. There’s torque aplenty, and the fuel-injection calibration is so finely tuned it makes the rider feel like he has the timing of a kung-fu champion. The \$12,999 Fury proves that radical design doesn’t have to produce an impractical bike. —BARRY WINFIELD

2 2009 Yamaha FZ6R

Compadre

Not everyone needs the explosive power and knife-edge handling of most 600-cc sportbikes—or the backache-on-wheels riding position either. Yamaha’s potent YZF-R6 is a beast. So there’s a niche for a detuned version with more bottom-end grunt and taller handlebars—like the new \$7090 FZ6R. Instead of the higher-end YZF-R6’s alloy structure, the 467-pound FZ6R uses welded steel for the frame and swing arm. We spent a full, albeit chilly day chasing twisties through Sonoma County, Calif., finishing up with a blast down to Big Sur. This easygoing bike feels like an old friend. There’s no learning curve and no need for muscle relaxants after a full day’s ride, thanks to the low, comfy saddle and rear-mounted foot pegs. —MIKE ALLEN

At 78 hp, the FZ6R’s powerplant is based on last year’s 600-cc YZF-R6 inline four-cylinder. The bore and stroke are the same at 65.5 by 44.5 mm, and the compression is still a healthy 12.2:1. But cam timing and fuel delivery have been revamped to lower the torque peak and fill in the bottom regions of the torque curve.



THINK OF IT AS ADDITIONAL HEALTH INSURANCE

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*...where we've always believed
better sleep can make you healthier.*

These days, it seems like more and more people are understanding the relationship between better sleep and better health. So we're proud that our authentic Tempur-Pedic mattress is the only mattress that is recommended worldwide by more than 25,000 health care professionals. They know that you can cover a traditional mattress with padding or a pillow-top, but you can't hide the truth: Those metal springs can create painful pressure points. But every Tempur-Pedic is filled with our unique Swedish TEMPUR® material, which absorbs pressure, cushioning your body for the kind of sleep you just can't get on a bed of metal springs. So we genuinely believe that when you choose your next bed, it can also be a healthy choice. Call for more information.



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or visit us online at www.TempurPedic.com



1 2011 Porsche Cayenne S Hybrid

2 2009 Infiniti G37 Convertible

3 2010 Jaguar XFR

Sign of the Times

Can a hybrid Porsche be a real Porsche? Perhaps. Tucked between the supercharged 3.0-liter V6 and the eight-speed automatic of this Cayenne is an electric motor. Combined, the system delivers 374 hp—only 11 less than the V8 Cayenne. We drove a prototype in Germany and found the performance impressive. Listen closely and the supercharger can be heard whining; the steering feels well connected to the pavement, and the tires sutured to the road. Like other hybrids, the engine shuts down to save fuel, and it can whirr along on battery power up to 30 mph. But the innovation comes from “sailing,” a clutch system that allows the Cayenne to glide at high speeds with the engine completely off. Expect it to command \$7000 over the Cayenne S. — JOHN PEARLEY HUFFMAN

Structural Integrity

Two key challenges, when creating a convertible model of an existing sporty car, are to preserve body-structure stiffness and maintain agility. The new G37 convertible succeeds on both counts. It is 435 pounds heavier than the coupe, thanks mostly to bracing added to ensure rigidity in the absence of a fixed roof. Yet we found the 2-ton droptop nearly as fun as the original on the curvy roads near Malibu, Calif. The metal top folds away in 30 seconds, letting you hear the full song of the Infiniti's 325-hp 3.7-liter V6. And that Six makes the sweetest sounds this side of Stuttgart. The innovative climate control system adapts its output to the speed of the car, so you stay comfortable whether the top is up or down. There is one drawback: As in most droptops, there's precious little trunk space (2 cubic feet) when you're running alfresco. — BEN STEWART

Sharpened Claws

The 510-hp XFR is the Type A personality wildcat in Jaguar's lineup. Click the shifter into the D position and prepare for the surge. Even under light throttle, there's a swell of torque. The six-speed automatic is brilliant too. Shifts can be “stacked,” if necessary. Pull the left paddle back several times and the transmission will remember how many shifts you've preselected and execute those downshifts only when engine rpm allows. Yes, it almost feels like cheating. At Spain's Montebelco Circuit, we shut the stability system off and enjoyed tremendous tail-wagging, tire-sliding fun. The \$80,000 XFR exhibited rock-solid stability at speeds approaching 140 mph.

— BASEM WASEF

PM TEST
DRIVEN

4



5



2010 Mercedes-Benz E550

Business Class

More than 22 million miles were logged developing the new E-Class. That was the company's most comprehensive test to date, and for good reason—the E-Class is the core of Mercedes-Benz. The car's new skin boasts a slippery 0.25 drag coefficient, equal to a new Prius. A 268-hp 3.5-liter V6 powers the E350, but we spent most of our own test time in Madrid driving the 382-hp V8-powered E550. The car's ample steering feel inspires confident maneuvering, while the seven-speed automatic makes the most of the V8's thrust. And the posh, serene interior just might steal some comfort-oriented buyers away from its Bavarian rival. —BASEM WASEF

2009 Aston Martin DBS

Rock Star

A six-figure supercar might seem like a tough sell these days. But for those whose net worth allows it, the \$269,000 Aston Martin DBS is brisk enough for the autobahn, discreet enough for Bond. The V12 delivers 510 hp and 420 lb-ft of torque. It sounds so good we'd want to keep the windows down permanently. The ride is surprisingly stiff—especially when the shocks are firmed—but the tradeoff is an ability to trace an arc with max precision. —B.W.

→ Chevy Silverado Hybrid | Honda Fury | Jaguar XFR | Mercedes-Benz E550 | Porsche Cayenne S Hybrid |
Infiniti G37 Convertible | Yamaha FZ6R | Aston Martin DBS X

→ First Look
Mercedes-Benz SLS AMG



FIRST LOOK: 2011 Mercedes-Benz SLS AMG

FUTURE SUPERCAR

It's been more than a half-century since Mercedes-Benz unveiled its iconic 300SL Gullwing. This upcoming AMG sports car just might be bold enough to properly honor that legend. The SLS AMG's 6.3-liter 571-hp V8 delivers 479 lb-ft of torque, runs a dry-sump lubrication system and is matched solely to a new AMG dual-clutch seven-speed transmission via a carbon-fiber prop shaft. Performance, we hear, will be wicked—exceeding that of the outgoing \$495,000 SLR McLaren—for far less money. —B.W.



The SLS AMG will be built around a cast and extruded aluminum space frame that tips the scales at just 531 pounds.

Italian Americans

ARE WE READY FOR FUN, FUEL-EFFICIENT EUROPEAN CARS? IF MINI'S SUCCESS IS ANY INDICATION, YES. THE PROPOSED FIAT-CHRYSLER ALLIANCE COULD BRING SOME SPRIGHTLY RIDES TO U.S. SHOWROOMS SOON. HERE'S A LOOK AT THE LIKELY CANDIDATES. BY ANDREW ENGLISH

1



2



→ 1

2009 Fiat Grande Punto

Fiat's sales volume comes from the micro-size Panda, but the profits are in the larger Grande Punto, which is about 5 inches longer than a Honda Fit. The turbo 1.4-liter will hit 60 mph in under 9 seconds. A sporty Abarth packs 180 hp and sprints to 60 mph in 7.7 seconds. The Grande Punto might be badged as a B-car for Chrysler, and the Abarth could create an inexpensive hot rod for Chrysler's SRT division.

→ 2

2009 Fiat Panda

The people's Fiat, the tiny Panda—15 inches shorter than a Nissan Cube—is affordable and roomy for its diminutive size. Drivetrains range from

a 1.0-liter that returns nearly 50 mpg, up to a 1.4-liter 36-mpg. So the boxy Panda could be a hip Scion competitor. The 4x4 version could become a fuel-efficient Jeep.

→ 3

2009 Fiat 500

The Fiat 500 is like a mini-Mini—in both size and price. In its footprint, it's nearly identical to its chassis-mate, the Panda. But the 500 is a retro-chic take on the '57 original. And because it has the global cachet to sell in Chrysler's showrooms as a Fiat, it might be the first to arrive in the U.S.

+

↓

HYBRID TAX CREDITS

Under the stimulus act's tax rebate for plug-in hybrid cars, a 4-kilowatt-hour battery will qualify for a \$2500 rebate, with another \$417 for each additional kwh, up to a total of \$7500. Chevy's Volt, with a 16-kwh battery, will be eligible for the maximum. Bigger packs mean heavier, more expensive cars. A recent Carnegie Mellon University study suggests hybrids with smaller batteries could be a more cost-effective way to reduce our nation's fuel use.

— LARRY WEBSTER

↓

DIESEL DELAYS

Low fuel prices and the tough economic climate are affecting diesel engine development. GM canceled plans for its new 4.5-liter V8 diesel. This innovative engine featured cylinder heads with integrated intake and exhaust manifolds. It produced over 300 hp, yet returned 25 percent better fuel economy than a similar gas V8. We hear Nissan is likely to delay the diesel Maxima. Acura may do the same with its diesel. But VW, whose buyers are diesel enthusiasts, reports strong demand for the Jetta diesel. — L.W.

Advanced friction technology. Didn't expect that in a hunk of clay, did you?

Mothers California Gold® Clay Bar. Designed to do what washing and polishing alone can't, this exclusive system incorporates a shearing process known as advanced friction technology to



remove harmful contaminants such as bird droppings, airborne metal particles, brake dust and tree sap. All without scratching your paint. The result is a finish that feels and looks showroom new. **Visit us at Mothers.com**



SPRAY, CLAY, WIPE AWAY: STEP 1: Spray. Use Mothers® Showtime® Instant Detailer to lubricate your car's finish. **STEP 2: Clay.** Flatten clay and glide across lubricated surface until smooth. Contaminants are pulled out of the paint and suspended inside the clay so they can't be re-deposited elsewhere. Re-knead the clay when it becomes dirty. **STEP 3: Wipe away.** Dry excess Showtime® with a microfiber or terry cloth towel.

Mothers® Clay Bar Kit includes:
Two 80 gram clay bars
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Craig Burnett, Lead Chemist*



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A BOLDER NASA

> BY TOM JONES

> ILLUSTRATION BY DON'T WAKE ME UP

D

Dear Mr. President:

En route to the first lunar landing 40 years ago, Apollo 11's astronauts altered their course with a 3-second rocket burn that fine-tuned their aim to a point 69 miles above the moon. With your 2010 budget plan, you gave NASA a course correction, lifting the agency's funding 9 percent to \$18.7 billion. Your stimulus act added an additional \$1 billion. That combined amount—just 0.5 percent of all federal spending—may seem trivial amid the hundreds of billions earmarked to boost the economy. But your funding decisions will make or break America's status as the world leader in space.

You set NASA's agenda each year by proposing its goals and budget; it's up to Congress to approve or modify those directives and the job of the agency's administrator to carry them out. NASA is currently wrestling with a constellation of major challenges. Here are the moves you

A FOUR-TIME SHUTTLE ASTRONAUT ADVISES THE PRESIDENT ON HOW TO LEAD IN SPACE.

should make to keep the U.S. space program on the right trajectory.

First, Mr. President, resist shortsighted political pressure to delay the shuttle's retirement. You approved the Bush administration's plan to decommission the shuttle by 2010 and replace it with Orion, the first new American spaceship to be built in more than 30 years, but many will pressure you to keep the shuttle flying.

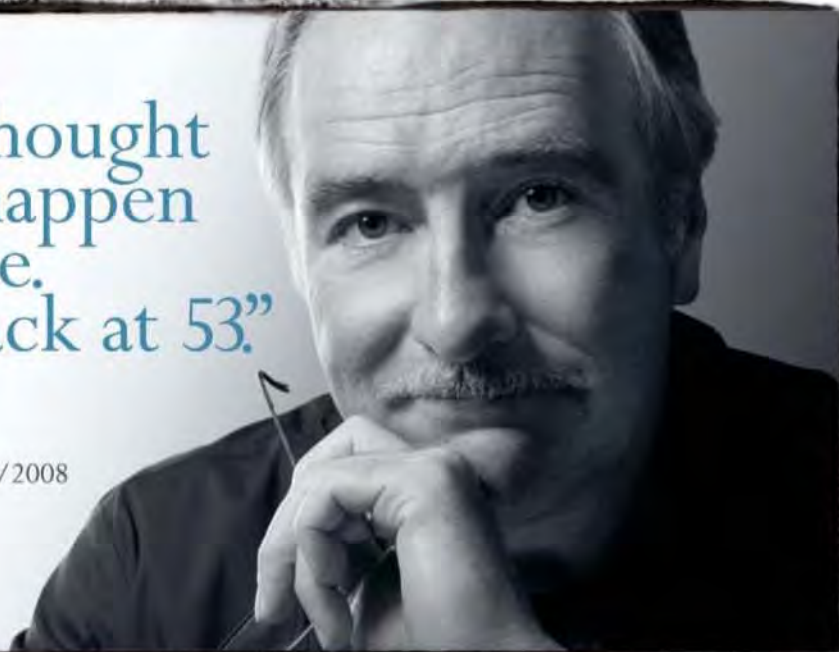
That would be politically expedient but counterproductive. The aging shuttle first flew nearly 30 years ago, and although two fatal accidents led to design improvements, it

is still a temperamental and risky vehicle. Cracks in three hydrogen-control valves delayed last winter's *Discovery* launch by more than a month. Tremendously versatile, the shuttle is also fragile, and every astronaut crew knows the risk: Any serious launch or entry failure will likely be catastrophic. The Russians, whose space future is heavily tied to the continued operation of the International Space Station (ISS), will find it in their interests to keep Soyuz capsules available to American astronauts until Orion finally takes flight in 2015.

Yes, we will miss the shuttle, but its operation costs more than \$3 billion a year. Money freed by its retirement should go directly to field the

"I never thought
it could happen
to me.
A heart attack at 53."

~Steve A.
New York, NY
Heart attack: 1/9/2008



"I had been feeling fine. But turns out my cholesterol and other risk factors* increased my chance of a heart attack. Now I trust my heart to Lipitor.
Talk to your doctor about your risk and about Lipitor."

- Adding Lipitor may help, when diet and exercise are not enough. Unlike some other cholesterol-lowering medications, Lipitor is FDA-approved to reduce the risk of heart attack and stroke in patients with several common risk factors, including family history, high blood pressure, low good cholesterol, age and smoking.
- Lipitor has been extensively studied with over 16 years of research. And Lipitor is backed by 400 ongoing or completed clinical studies.

*Patient's risk factors include age, gender, smoking, and high blood pressure.

IMPORTANT INFORMATION: LIPITOR is a prescription drug. It is used in patients with multiple risk factors for heart disease such as family history, high blood pressure, age, low HDL ('good' cholesterol) or smoking to reduce the risk of heart attack, stroke and certain kinds of heart surgeries. When diet and exercise alone are not enough, LIPITOR is used along with a low-fat diet and exercise to lower cholesterol.

LIPITOR is not for everyone. It is not for those with liver problems. And it is not for women who are nursing, pregnant or may become pregnant. If you take LIPITOR, tell your doctor if you feel any new muscle pain or weakness. This could be a sign of rare but serious muscle side effects. Tell your doctor about all medications you

take. This may help avoid serious drug interactions. Your doctor should do blood tests to check your liver function before and during treatment and may adjust your dose. The most common side effects are gas, constipation, stomach pain and heartburn. They tend to be mild and often go away.

LIPITOR is one of many cholesterol-lowering treatment options that you and your doctor can consider.

Please see additional important information on next page.



LIPITOR
atorvastatin calcium
tablets



Have a heart to heart with your doctor about your risk. And about Lipitor.

Call 1-888-LIPITOR (1-888-547-4867) or visit www.lipitor.com/steve

You are encouraged to report negative side effects of prescription drugs to the FDA.

Visit www.fda.gov/medwatch or call 1-800-FDA-1088.

IMPORTANT FACTS



LIPITOR
atorvastatin calcium
tablets

(LIP-ih-tore)

LOWERING YOUR HIGH CHOLESTEROL

High cholesterol is more than just a number, it's a risk factor that should not be ignored. If your doctor said you have high cholesterol, you may be at an increased risk for heart attack. But the good news is, you can take steps to lower your cholesterol.

With the help of your doctor and a cholesterol-lowering medicine like LIPITOR, along with diet and exercise, you could be on your way to lowering your cholesterol.

Ready to start eating right and exercising more? Talk to your doctor and visit the American Heart Association at www.americanheart.org.

WHO IS LIPITOR FOR?

Who can take LIPITOR:

- People who cannot lower their cholesterol enough with diet and exercise
- Adults and children over 10

Who should NOT take LIPITOR:

- Women who are pregnant, may be pregnant, or may become pregnant. LIPITOR may harm your unborn baby. If you become pregnant, stop LIPITOR and call your doctor right away.
- Women who are breast-feeding. LIPITOR can pass into your breast milk and may harm your baby.
- People with liver problems
- People allergic to anything in LIPITOR

BEFORE YOU START LIPITOR

Tell your doctor:

- About all medications you take, including prescriptions, over-the-counter medications, vitamins, and herbal supplements
- If you have muscle aches or weakness
- If you drink more than 2 alcoholic drinks a day
- If you have diabetes or kidney problems
- If you have a thyroid problem

ABOUT LIPITOR

LIPITOR is a prescription medicine. Along with diet and exercise, it lowers "bad" cholesterol in your blood. It can also raise "good" cholesterol (HDL-C).

LIPITOR can lower the risk of heart attack or stroke in patients who have risk factors for heart disease such as:

- age, smoking, high blood pressure, low HDL-C, heart disease in the family, *or*
- diabetes with risk factor such as eye problems, kidney problems, smoking, or high blood pressure

POSSIBLE SIDE EFFECTS OF LIPITOR

Serious side effects in a small number of people:

- **Muscle problems** that can lead to kidney problems, including kidney failure. Your chance for muscle problems is higher if you take certain other medicines with LIPITOR.
- **Liver problems.** Your doctor may do blood tests to check your liver before you start LIPITOR and while you are taking it.

Symptoms of muscle or liver problems include:

- Unexplained muscle weakness or pain, especially if you have a fever or feel very tired
 - Nausea, vomiting, or stomach pain
 - Brown or dark-colored urine
 - Feeling more tired than usual
 - Your skin and the whites of your eyes turn yellow
- If you have these symptoms, call your doctor right away.

The most common side effects of LIPITOR are:

- Headache
- Constipation
- Diarrhea, gas
- Upset stomach and stomach pain
- Rash
- Muscle and joint pain

Side effects are usually mild and may go away by themselves. Fewer than 3 people out of 100 stopped taking LIPITOR because of side effects.

HOW TO TAKE LIPITOR

Do:

- Take LIPITOR as prescribed by your doctor.
- Try to eat heart-healthy foods while you take LIPITOR.
- Take LIPITOR at any time of day, with or without food.
- If you miss a dose, take it as soon as you remember. But if it has been more than 12 hours since your missed dose, wait. Take the next dose at your regular time.

Don't:

- Do not change or stop your dose before talking to your doctor.
- Do not start new medicines before talking to your doctor.
- Do not give your LIPITOR to other people. It may harm them even if your problems are the same.
- Do not break the tablet.

NEED MORE INFORMATION?

- Ask your doctor or health care provider.
- Talk to your pharmacist.
- Go to www.lipitor.com or call 1-888-LIPITOR.

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SPACE EXPLORATION///
A BOLDER NASA

safer and more efficient Orion. With its sturdy, compact structure, robust heat shield and launch-abort system, Orion offers future crews a tenfold increase in safety. Most important, Orion can take us beyond low Earth orbit into deep space—somewhere the veteran shuttle can never go.

Nearing completion after a decade of construction, the ISS will be our only foothold in space until Orion makes its debut. Yet tight NASA budgets have starved the station of the vigorous scientific activities it was built to conduct. Let's get some payback for the many billions we have invested. Tell Russia, Europe, Japan and our other partners we will continue to use the station until at least 2020, and make the science investments that will keep its three big laboratories humming.

Research aboard the ISS, for example, has revealed a genetic "master switch" in salmonella bacteria that controls the microbe's capacity for infection. The discovery should help scientists design an effective vaccine for this dangerous germ; future research could lead to groundbreaking new treatments to combat infectious disease and improve our quality of life on Earth.

On one of its last flights to the ISS, the shuttle will deliver the Alpha Magnetic Spectrometer, designed to search for rare antimatter and to study the universe's mysterious dark matter. The station is also the perfect place to try out promising space technologies: spacesuits, life-support systems and radiation-protection techniques essential for voyages into deep space. Texas-based Ad Astra Rocket Co. will soon use the ISS to test its high-efficiency plasma rocket engine, a potential game changer for Mars exploration. Budget bureaucrats in the previous administration undermined the station; its productive future is in your hands.

Direct NASA to follow through with plans for using private industry to ship cargo to the space station.

Money saved through competitive bidding for those cargo services can then be spent on exploration. Getting U.S. firms off the launchpad is also the quickest way to eliminate our looming reliance on Russian rockets for cargo and crew transport to the ISS. If private cargo services are reliable and affordable, NASA may also contract for commercial spacecraft to give astronauts an economical lift to the space station.

Mr. President, your budget endorses NASA's return to the moon;

journey there, but leave no doubt that Americans will lead the way.

Send our explorers not just to the moon, but far beyond. Orion missions to nearby asteroids would reap new scientific discoveries, tap valuable space resources, gain knowledge to guard against a cosmic impact and inspire us with views of a breathtakingly distant Earth.

Use your bully pulpit to explain why space exploration will continue to be an American trademark. Tell the public that space is not just about

MR. PRESIDENT, YOUR BUDGET ENDORSES NASA'S RETURN TO THE MOON; SO DO LAWMAKERS. NOW DELIVER THE SUSTAINED FUNDING TO GET US THERE ... LEAVE NO DOUBT AMERICANS WILL LEAD THE WAY.



On a February 2001 mission to the International Space Station, the author connects power cables to a new lab.

so do lawmakers. Now deliver the sustained funding to get us there, a commitment the previous administration and Congress failed to live up to. China, India and other competitors recognize the economic and technological rewards of spaceflight. They are rapidly catching up to us in low Earth orbit and make no secret that the moon is their target. We should welcome partners on our

science—it's about exploring for resources and energy, creating new industries and finding economic opportunity. You should drive home the message that investment in space technology will keep our scientists and engineers keen and capable.

Generations of Americans found prosperity and forged our nation's future on the frontier. Look our young people in the eye and tell them that we need explorers—doers—who are citizens of the most forward-looking nation on Earth. Tell them America is signing up a world-beating corps of talented scientists and engineers and turning them loose to explore the moon, the asteroids and the solar system. That same team can conquer terrestrial challenges in energy, defense, environmental protection and high-tech competition.

Mr. President, reignite the excitement generated by Apollo 11 and the epic voyages that followed. Launch our future explorers to prove themselves at the frontiers of space. **PM**

Tom Jones, shuttle astronaut, planetary scientist and member of the PM Editorial Board of Advisers, explores the solar system with co-author Ellen Stofan in Planetology: Unlocking the Secrets of the Solar System.



BEYOND THE BUZZWORDS

> BY DAVIN COBURN

> PHOTOGRAPH BY CHRISTOPHER GRIFFITH

F

or years, anyone driving through Grapevine, Texas, just north of Dallas/Fort Worth International Airport, has needed patience—and a knack for navigating the maze of underpasses and off-speed merging lanes that make up the city's notorious "Grapevine funnel." That may change over the next five years, with an influx of funding provided by the \$787.2 billion American Recovery and Reinvestment Act (ARRA), which sets aside up to \$135 billion for infrastructure projects.

In addition to roads and bridges, initiatives such as smart electric grids and high-speed rail received funding—along with attention from politicians and pundits quick to seize on a new set of buzzwords. There's just one problem: While the law was designed to provide immediate stimulus to the economy, only a portion of the infrastructure pot targets areas where money can be dispersed both quickly and wisely. The risk of wasteful spending and missed opportunities seems great. But so does the potential to address real infrastructure challenges—and we know where to begin. Here are five of the most critical issues addressed by the legislation, and what PM thinks should be done with the money.

SMART ELECTRIC GRID \$4.5 BILLION

→ The smart grid has become a favorite talking point for policy-makers. Since 2005, a number of test projects have shown how better sensors, communication devices and

THE STIMULUS ACT SETS ASIDE BILLIONS FOR INFRASTRUCTURE PROJECTS. NOW WHAT?

control systems eventually could make power generation, transmission and usage more efficient and reliable. Ultimately, the smart grid may prevent disruptions like the one that left 50 million residents of the Northeast without power in 2003.

Where to start? Promising grid upgrades are already underway in Boulder, Colo., and Austin, Texas. But before expanding such programs, we should give the National Institute of Standards and Technology the time it needs to untangle an emerging Gordian knot of overlapping technologies. (The ARRA provides funding for this effort.) "There are about 200 different standards that apply to the technology in the smart grid, and another 60 or 70 that apply to smarter appliances," says Kurt Yeager, executive director of the Galvin Electricity Initiative. "If the socket in the wall only matches one manufacturer's appliance, that's not going to work."

WATER SYSTEMS **\$6 BILLION**

→ Droughts and population growth have left 36 states facing potential drinking-water shortages within the next five years. Coping with the crisis may require everything from higher water rates to more gray-water recycling. Some measures will be controversial, but plugging leaks shouldn't be—and billions of gallons of water leak from faulty municipal pipes each day.

Where to start? The first step in reining in the waste is to figure out exactly where leaks are likely to occur, and with what severity. "If there's a pothole in a road, you see it, you complain," Virginia Tech professor Sunil Sinha says. "The challenge here is no one complains because you can't see the problem."

Last year, Sinha spearheaded a project with the Environmental Protection Agency to create a national database of water systems, with interactive maps and tools for predicting failures. Utility companies in 17 major cities are cooperating, but many smaller utilities can't afford to participate. Currently, \$10 million

devoted to data collection might do more good than a dozen pricier water projects that lead to ribbon-cutting ceremonies.

HIGH-SPEED RAIL **\$8 BILLION**

→ Americans spend hundreds of millions of hours each year waiting for delayed flights, and 4.2 billion hours a year stuck in traffic. A partial answer that has been trumpeted for decades is a network of bullet trains like those in Europe and Japan, which zip along at 180 mph or more.

Where to start? There's just one problem with Euro-style bullet trains: They require new track, and building even a small regional system would cost many times the \$8 billion set aside in the legislation. The realistic alternative is to upgrade existing lines for low-level high-

THERE'S JUST ONE PROBLEM WITH EURO-STYLE BULLET TRAINS: EVEN A SMALL SYSTEM WOULD COST MANY TIMES THE \$8 BILLION SET ASIDE IN THE ACT.

speed rail, with trains that run at 110 mph. A good candidate for such an upgrade is the Midwest Regional Rail System, which could link nine states and most of the Midwest's population centers. Higher-speed trains would cut travel time from Chicago to St. Louis or Detroit, providing a viable alternative to driving and reducing pressure on the overcrowded O'Hare International Airport. The estimated cost, conveniently, is \$8 billion.

ROADS AND BRIDGES **\$27.5 BILLION**

→ A new study by the American Society of Civil Engineers estimates that one-third of major U.S. roads are in poor or mediocre condition, and 26 percent of the nation's bridges are either structurally deficient or functionally obsolete. The situation is nearly unchanged since the ASCE released its previous report, in 2005.

Where to start? Some of the first highway projects funded under the ARRA were "pavement rehabilitation" in New Hampshire and road-way resurfacing in Maryland. Such maintenance is important, but it won't improve transportation over the long haul. A better model is supplied by the Texas Department of Transportation, which is ready to go with a number of meaningful projects that have been planned for years, notably a new 16-mile route through Grapevine. The roadways promise to reduce congestion, benefiting the local economy while reducing pollution and delays.

AIR TRAFFIC CONTROL **UP TO \$150 MILLION**

→ Last year, nearly one in four U.S. flights was delayed. The Federal Aviation Administration anticipates

increasing air travel—and a painfully slow update of the creaky air traffic control system that exacerbates delays. Implementing NextGen, an overhaul that will include new radar and cockpit technology, could cost \$35 billion through 2025. The ARRA missed an opportunity by providing only \$150 million for the initiative.

Where to start? NextGen already is improving operations at major airports in Atlanta, Dallas and Phoenix. According to the Air Transport Association of America, six major components of the system—from updated satellite technology to display upgrades—are ready to go. This is one instance where Congress should allocate more money. NextGen isn't vaporware. It's real technology that the country needs now. **PM**

 **ON THE WEB** > Access PM's extensive reporting on infrastructure at popularmechanics.com/rebuilding.

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Eco + **Muscle**

PART II



In last month's issue, we dramatically increased the performance of a 2009 Dodge Challenger. To raise engine output from 370 hp to over 500 hp, we added ZEX nitrous injection, a high-flow induction system, Pulstar Pulse plugs, headers, free flow exhaust, low-restriction Wix filters and Mobil 1 Extended Performance synthetic oil. We also purged the fuel system using Gumout Regane, replaced the stock battery with a more efficient Exide Premium 60 battery and reprogrammed the ECU using a Diablo Predator Flash Tuner.

To handle the extra power we added a Richmond 3.55:1 ring and pinion, Quaife limited-slip differential, Pedders aftermarket racing-style suspension system, Razors Edge shock tower brace, Bilstein gas-pressurized shock absorbers, Brembo GT disc brakes and wide, ultra-performance Michelin Pilot Sport PS2 tires on 20-in. Avarus AV5 rims.

To help the power-to-weight ratio of our two-ton muscle car, we replaced the hood and decklid with lightweight carbon fiber parts from Seibon Carbon, plus removed a lot of heavy and extraneous OEM covers and trim pieces. We replaced some OE Dodge parts with ones from Rockauto.com, and researched our project every step of the way through a variety of Haynes manuals.

FAST AND FRUGAL

Dodge's MDS VCT cylinder deactivation software allows our modified Challenger to still return 25 mpg at highway speeds which is spectacular for a car this heavy and this quick. All our modifications have not only increased performance, but efficiency, too.

How quick is quick? It now runs 0 to 60 in 3.95 seconds and the quarter-mile in 12.4 seconds at 114 mph, yet stops shorter than most lightweight sports cars and circles the skidpad at 1.2 G. That's on street-legal Michels!

ECO+

Having successfully built our Challenger into a fun-to-drive American muscle car, this month we're adding the "Eco" portion to our project. As far as we know, nobody has ever tried to build a hybrid muscle car like this before. We're truly breaking new ground with Eco+Muscle.

PARALLEL POWER

Unlike most hybrid cars that blend the power from a small gas engine and a small electric motor to achieve acceptable performance, Eco+Muscle now has two separate parallel powertrains, gas and electric, each one independently capable of driving the car.

The idea is simple. On the highway, where safe passing and long-distance capability are important, our Challenger runs solely as a high-performance muscle car. In the city, at lower speeds, our Challenger is an ultra-low emissions electric that delivers full torque from rest. It's the best of both worlds.

UQM ELECTRIC

We started by contacting the electric car experts at Evolve-It Motors. They suggested we use a Power Phase 125 System made by UQM Technologies, Inc. The heart



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of this system is an SR218 liquid-cooled, brushless DC electric motor.

UQM's motor is amazing. A mysteriously monolithic cylinder less than 9-in. long and 11-in. in diameter, it weighs just 89 lbs. but produces 125 hp and 176 lb-ft of

torque while revving smoothly to 8000 rpm.

Like all electric motors, 100 percent of the available torque is developed from zero rpm, as opposed to the typical internal combustion engine that slowly develops torque as the revs increase. This little electric motor is comparable in performance to a typical V6 rated at 250 hp.

Along with the motor, UQM supplied a DD45-500LWB liquid-cooled inverter/controller that contains a programmable digital signal processor. The inverter/controller draws power from the battery pack and feeds it into the motor, then controls the charge

returning to the batteries during regenerative braking.

BATTERY POWER

We turned to Exide, which has been making batteries for electric vehicles for 120 years. Exide engineers recommended their ORB34DC-36 Select Orbital Marine Deep Cycle as the best compromise between weight, price and performance. This battery is rated at 750 CCA and 925 CA—sufficient for our use.

Exide's innovative cylindrically-wound orbital design uses ultra-thin lead plates sandwiched with absorbent glass mats. The result is a safe, sealed, leak-proof power source that can be mounted in any position and needn't be vented. It also weighs significantly less than a conventional lead-acid battery.

In the near future, new battery technologies will allow electric vehicles to use smaller and lighter batteries such as lithium-ion.

TWENTY-EIGHT BATTERIES

UQM's motor requires at least 250 volts to operate, 300 to 425 volts to run properly. We can pack 336 volts into a surprisingly compact battery pack of 28 Exide Select Orbitals connected in series.

In other words, not only do we have to find room for our electric motor, controller and cooling system, but 28



KICKER

Stillwater Designs assembled its first sound system in 1973 and the world's first automotive full-range speaker box in 1980. This was called "Kicker" because it fit behind the seats of a pickup truck and when you turned the volume up, felt like a kick in the pants!

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batteries. To minimize electrical transmission losses, all these components need to be mounted as close to one

another as possible and connected with the shortest possible wires. To preserve handling, the mass needs to be evenly distributed side-to-side and concentrated within the wheelbase for the lowest polar moment of inertia for optimal handling.



EXIDE

The company that is now Exide started in 1888 as the Electric Storage Battery Company and in 1890 provided batteries for the world's first electric streetcars. By 1900, lightweight "Excellent Oxide" or Exide batteries powered thousands of electric taxicabs in cities around the world.

Over the next century, Exide batteries went everywhere from Antarctica with Commander Byrd to the International Space Station with the NASA Space Shuttle. In 1999, Chairman Bob Lutz launched the cylindrically-wound Exide Orbital battery, the first innovation in battery technology in decades.

Today, Exide makes batteries for virtually every vehicle in or out of this world.

LEARN MORE AT EXIDE.COM

PACKAGING

What we have here is a packaging problem. There is only one possible solution; Eco+Muscle has to be a two-passenger car with a back seat area full of batteries. Conveniently, the Challenger has an independent rear suspension, which means the driveshaft from the transmission to the solidly-mounted differential does not have to move up and down as it would with a live rear axle.

Even more conveniently, the Challenger uses a two piece driveshaft with a fixed support in the middle. It was logical that we could replace the rear driveshaft with the electric motor, using custom-machined adapters to splice the motor shaft into the sectioned driveshaft.

The Challenger has a gas tank that lives under the rear floor area and cradles the driveshaft like a cowboy's saddlebags. Obviously, the stock gas tank had to go.



FUEL CELL

The Challenger has a spare tire well under the trunk floor, but comes with a sound absorbing block of foam rather than a spare tire. Remove the foam, and an ATL SU115 Super Cell 15 gallon fuel cell fits perfectly with just a little trimming of the wheel well. The fuel cell requires an external fuel pump, which we sourced from Aeromotive.

CUT OUT THE FLOOR, THROW AWAY THE BACK SEATS

To mount the electric motor, we had to cut out the floor in the back seat area, then fabricate and weld in a new floor a few inches higher. The UQM motor bolts to a massive mounting plate we machined from 0.75-in. aluminum. This, in turn, bolts to mounting tabs welded to the frame rails.

With the rear seats removed, we had to fabricate a firewall to cover the passageway from the trunk to the interior, safely separating the fuel cell from the battery

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Here's how it works: electrical energy from the engine's power coil is stored in the pulse plug's built-in capacitor. At the exact moment needed, that energy is released in an amazingly quick (two nanosecond), powerful, high-energy pulse.

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pack. The firewall turned out to be a perfect spot to mount both the inverter/controller and the onboard plug-in battery charger, right above the UQM motor, right behind the battery pack.

COOLING SYSTEM

The electric motor and inverter/controller are liquid-cooled. We purchased a Derale Low-Profile Electra-Cooler with electric fan that fits neatly in front of the stock V8 radiator and is plumbed back to the motor and inverter/controller with Aeroquip -8 AN lines. As it worked out, we were able to route the cooling lines parallel to the Aeroquip fuel lines connecting to the fuel cell.

BATTERY PACK

Remarkably, the 28 Exide Select Orbital batteries fit into a two-level rack just 4 feet wide by 2 feet long by 20-in. high. We fabricated a sturdy rack from aluminum angle, solidly bolted to a frame cross-member and to the frame rails on either side.

We fabricated covers for the front and top of the battery pack framing a clear polycarbonate panel so that curious bystanders can look into the back and see a sea of Exide batteries. We've even rigged up a few LED lights to illuminate the batteries when the car is on display.

DUAL THROTTLES

Because we have two completely separate parallel drive systems, we wanted to have two separate throttles as well. We've set things up so the Hemi V8 is controlled by the stock throttle pedal, while the electric motor is controlled by a hand throttle. Theoretically, a driver with excellent coordination could accelerate using both the V8 and electric motor at the same time, dumping insane amounts

of torque into the differential.

We found a 0 to 5 amp potentiometer equipped with a motorcycle-style twist grip. We got that idea from some off-road truck racers who steer with one hand and use a twist grip mounted on a stalk as a right-hand throttle. If it works in a race truck, we figure it might just work in the demanding conditions of city driving.



E-METER

The final piece of the electric drive system is a Xantrex Link Pro Battery Monitor mounted in the dash. This keeps track of volts, amps, amp hours and operating time. A simple bar graph shows the state of charge.

INTERIOR

The stock Challenger bucket seats are just too large and heavy for this project. We bought a pair of Corbeau black bucket seats that are considerably more compact, much lighter and designed to hold you in place like racing seats.

To brighten the Dark Slate interior, we reupholstered the Corbeau seating areas with Novatex Unisuede in Perforated Hot Rod Blue, then sprayed accent surfaces in the interior with Dupli-Color spray paints to match.

KICKER

Stillwater Designs, manufacturer of Kicker sound systems, now produces components custom-made for



**More miles.
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1 - Compared to Goodyear® Assurance ComfortTred in wet testing. 2 - Compared to Goodyear® Assurance products. 3 - Category defined as premium-priced S & T speed-rated passenger products. 4 - Manufacturer's limited warranty. See warranty book details. Copyright ©2009 Michelin North America, Inc. All rights reserved. The Michelin Man is a registered trademark owned by Michelin North America, Inc.



virtually all Chrysler, Dodge and Jeep models. Called Mopar Performance Audio, these come in Stage 1, Stage 2 or Stage 3 kits that replace or supplement the factory sound system.



MEGUIAR'S

"Car Crazy" radio and TV personality Barry Meguiar is the latest to run this family company since his grandfather started mixing furniture polish in grandma's kitchen in 1901. Over the years, Meguiar's has grown into a huge corporation, but has never lost that personal touch.

Meguiar's newest line of automotive products is called NXT Generation, and includes Car Wash, Tech Wax 2.0, Spray Wax, Tech Protect, Insane Shine Tire Coating, Speed Detailer and Glass Cleaner.

Meguiar's manufactures over 300 separate cleaners and protectants for automotive, marine, aviation, industrial and home use.

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For example, the Kicker Stage 3 kit includes a Kicker 4.1 channel amplifier upgrade that plugs into the dash next to the stock Dodge head unit. The front doors get 6x9-in. two-way speaker systems, while the package shelf gets a pair of 6-in. round two-way speaker systems.

Lastly, we installed a custom sound box that is specifically designed to fit the Challenger trunk and contains a 400-watt amplifier plus dual 10-in. square subwoofers. Best of all, the Kicker components come with the proper connectors and simply pop into the proper mounting holes. Installing Kicker's

Stage 3 Mopar Performance Audio was the single easiest task in this entire project.

DUPLI-COLOR

Dupli-Color makes a great variety of spray paints. In order to get a true color when painting over the charcoal plastic in the interior, we first used Dupli-Color Metalcast Ground Coat as a light-colored base. Depending on the surface, we went over that with Dupli-Color Vinyl and Fabric or Dupli-Color Metalcast in blue to match our Unisuede.

PAINT SHOP

Our Challenger came from the dealer painted Stone White. After we replaced the hood, top and decklid with carbon fiber, it looked cool but we wanted an exterior paint job that expressed the "eco" nature of our project while still retaining the "muscle."

Dupli-Color designed a paint scheme combining green and blue that's perfect for our hybrid vehicle. Dupli-Color makes a ready-to-use lacquer system called Paint Shop that consists of primer, color coat and clear coat. There are straight paint colors available, but also metallic and candy apple colors.

After scuff sanding the whole car, we painted everything but the carbon fiber with Paint Shop BSP100 Primer, over which we used BSP201 Championship White.

After masking everything but the sides, rear and lower front valence, we sprayed those areas with BSP306 Candy Basecoat Silver. This contains a lot of metallic silver particles to enhance the depth and shine of the color coat.

Then we masked off a wide stripe down each side. Most of the car was painted with BSP204 Deep Blue,

Dupli-Color

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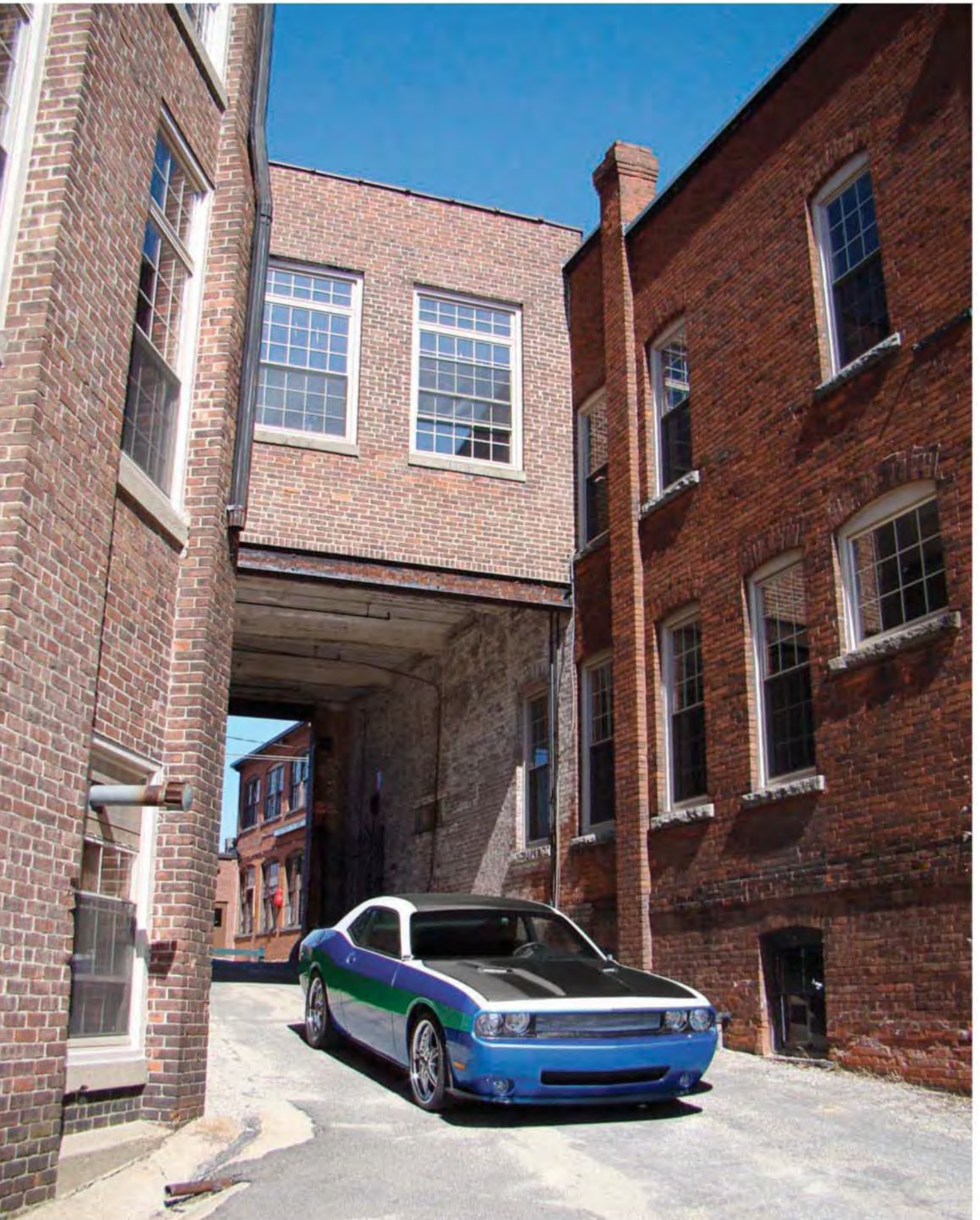
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which has a metallic component. Then we covered everything but the side stripes and sprayed BSP304 Candy Apple Green over the silver basecoat.

The green color coat is translucent and fades from a bright silvery green at the front to a deep green at the rear.



MICHELIN

Edouard and Andre Michelin made their first tires in 1889. In 1898, the Michelin Man, made from a stack of tires and named Bibendum ("Cheers!" in colloquial Latin) made his first appearance.

Today, 110 years later, Bibendum is one of the best-known corporate symbols on earth, and Michelin is a worldwide conglomerate making tires for not only every imaginable car and truck, but everything from bicycles to earthmovers, racing cars to airliners.

Michelin has always been very green, among other things manufacturing Energy Saver tires and sponsoring the Michelin Green X Challenge. Michelin also produces its famous maps and Michelin guides.

LEARN MORE AT MICHELIN.COM

This requires painting the whole green area with one coat, then progressively fading to four coats at the rear.

Once the color had set, we sprayed the entire car, including the carbon fiber panels, with BSP300 Clear Coat. Finally, we striped the breaks between each color area with a 0.12-in. gray metallic stripe. This once-stark white Challenger is now a dramatic custom with paint that'll grab attention at every corner.

CARBON AERODYNAMICS

To at least partially compensate for loading half-a-ton of batteries into the back seat area, we

decided to improve the aerodynamics and power-to-weight ratio of Eco+Muscle. At the front, we replaced the stock front fascia with a carbon version from Seibon Carbon.

To finish out our carbon fiber theme, we replaced the small front fender flares, the stock black plastic rockers and the rear valence with carbon fiber, too. Seibon Carbon supplied a carbon fiber rear spoiler to match their carbon fiber decklid.

We obtained a genuine NASCAR carbon fiber front splitter and installed that in place of the stock black plastic spoiler. We're not sure whose "Car of Tomorrow" originally carried the splitter, but it was painted bright yellow and proudly exhibited "banking burns."

DETAILS

For improved aerodynamics, we removed the stock rearview mirrors and replaced them with a trio of "keyhole" video cameras from RV Cams. Each little camera is only 1-in. in diameter, but delivers a 120-degree wide angle image. We mounted one in the center of the rear spoiler pointing straight back and one at the leading edge of each side window, angled to give a clear view of traffic. The three cameras all feed to a 7-in. rectangular screen that shows the scene from all three simultaneously.

FUEL AND PLUG

The 2009 Challenger was deliberately designed to be reminiscent of Dodge's landmark 1970 Challenger, one





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of the most beautiful of all classic muscle cars. One of the design hallmarks of the original Challenger is a large,

round, chrome fuel filler on the left rear fender. Naturally, Dodge designers included this on the contemporary version.

We obtained an identical fuel filler and welded it into the fender on the right side. We recreated a new piece of trim reading “Plug” to match the “Fuel” on the other side. Why? Because our Challenger is now a hybrid with two power sources. You plug in the onboard charger using a cord that snakes out of the right side filler.

MEGUIAR'S

When our project was finished, we cleaned the windows inside and out with Meguiar's NXT Generation Glass Cleaner, waxed the new Dupli-Color

paint job with Tech Wax 2.0 and cleaned up the Michelin tires with Insane Shine Tire Coating. For photo shoots and car shows, we'll keep everything clean using microfiber towels and NXT Generation Speed Detailer.

We've used Meguiar's products for decades on classics and project cars, and never been disappointed. The new NXT Generation synthetics are the best car care products yet. Examine our Challenger when it's on display and see if you don't agree.

TOURING THE COUNTRY

The world's first parallel hybrid/ solar/plug-in muscle car will be displayed at the NASCAR Pocono 500 race in June, the San Bernardino Route 66 Rendezvous in September and the Las Vegas SEMA Show in November. It really is a stunning vehicle, be sure to come visit us and gauge for yourself.

HOW DOES IT DRIVE?

So far, we've built a remarkable muscle car, then turned it into a hybrid that can be driven using just the electric motor. It won't accelerate 0 to 60 mph in 4 seconds on battery power, but it will handily out-run city traffic and zip up to 100 mph. Driving reasonably, most commuters could handle a 40 mile daily round trip totally on battery power, then recharge the battery pack overnight from a 120-volt outlet, ready for tomorrow.



DUPLI-COLOR

Dupli-Color dates to 1938, when Lieutenant Colonel Sigmund Edelstone started selling little bottles of touch-up paint equipped with a handy brush in the bottle cap. Seven decades later, Dupli-Color is a division of the world-famous paint company begun by Henry Sherwin and Edward Williams in 1866.

Sherwin-Williams markets a wide array of automotive paints, primers and coatings under the Dupli-Color name. Most Dupli-Color products, from adhesion promoter to wheel coating, are available in spray cans.

There's also Dupli-Color Paint Shop, a professional-quality three-step lacquer system—primer, color, clear coat—available in pints. Paint Shop is what we used to paint our Challenger.

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Unlike a pure electric vehicle, if you do run out of battery power, you can just start the Hemi, shift into Drive and motor on, spinning the electric motor in Regen mode and recharging the batteries as you go. It really is the best of both worlds, Eco+Muscle.

IT'S NOT DONE

A breakthrough project like this is never finished. At this point, we still need to have the Hemi V8 idling and the transmission in neutral when driving in electric mode, because the power steering, power brakes and transmission

lubrication pump are dependent on the gas engine.

Our next step is to figure out ways to drive these systems with electric motors. So honestly, at the moment, our fuel flow meter says we're getting about 99 miles-per-gallon in electric mode. That's a huge improvement, but not the gas-free, pollution-free driving we're after.

We also want to incorporate an overdrive unit that will improve mileage with the Hemi yet improve acceleration with the electric motor. So far, we haven't been able to reprogram the Challenger ECU to accept such a dramatic change in the final drive ratio.

To help keep the batteries charged, we bought a set of PowerFilm 15-volt, 100 ma flexible solar panels from Sundance Solar. Each polyester-encapsulated panel is 10x6 inches, but laid out end to end in two rows, they create subtle racing stripes down the center of our carbon fiber hood, top and trunk lid. On a sunny day, our racing stripes recharge the battery at a rate of 2.5 amps.

ONLINE

On our website, you can see a variety of videos with more details of the different areas of our Eco+Muscle Challenger, plus see it in action running on both the Hemi and the UQM electric motor at the track and on public roads. You'll also be able to follow along on as we continue refining and improving the car.

Our goal is to arrive at November's SEMA Show with a high-tech hybrid that not only looks good and shows a new direction for the auto industry, but that runs as seamlessly in electric mode as it does behind a muscular Hemi. ♦

A DAY WORKING ON THE CAR WITH MY DAD.

Instead of school I did work on a 2002 Suburban. The hub assembly blew out. We used Haynes Repair Manual to help fix it. My dad did most of the work and I did all of the reading. There was 11 different steps. We had to replace the speed sensor, hub assembly, greased all the spines and put it all back together. Haynes Repair Manual was a really big help to my dad and so was I. The funnest part was test driving it because I knew we did a good job.

Bailey B.



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THE UNTOLD STORY OF APOLLO 11

It was the most famous step in human history. When Neil Armstrong's boot first touched lunar soil on July 20, 1969, the event was celebrated worldwide as a triumph for humankind. And yet the hazy television images broadcast from space failed to convey the true audacity—the enormous risks, the technological complexity, the intricate teamwork—of the mission that put two Americans on the moon. To mark the 40th anniversary of Apollo 11, POPULAR MECHANICS set out to document the full and unvarnished story. We interviewed more than three dozen flight controllers, engineers, scientists and astronauts, who described their roles from liftoff to splashdown. Here, the genuine drama of Apollo 11, in their own words.

PM'S REPORTING TEAM INCLUDED JENNIFER BOGO, DAVIN COBURN, ADAM HADHAZY, JOE P. HASLER, ERIKA CHECK HAYDEN, CLARA MOSKOWITZ, DAVID NOLAND AND ELIZABETH SVOBODA. AN EXTENDED VERSION OF THIS ORAL HISTORY, ALONG WITH ARCHIVAL PHOTOGRAPHS AND AUDIO, IS AVAILABLE AT popularmechanics.com/apollo11turns40.

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Apollo 11 astronaut Buzz Aldrin captures the shadow he casts on the lunar surface with a 70-mm Hasselblad camera mounted to his spacesuit.



JULY 16, 1969—LAUNCH DAY

• **JoAnn Morgan**, instrumentation controller, *Apollo Launch Control, Kennedy Space Center*: The pad at night was just glorious to see with the whole vehicle bathed in these giant xenon lights. Because I got there before 3 am, it was near the very end of the propellant loading; there was a little venting of the liquid oxygen. It was just an enchanting sight to see, and I had the most positive feeling that this launch was going to be successful from the minute I parked my car and walked up to the firing room.

• **Jay Barbree**, correspondent, *NBC News*: I'd been feeding radio spots until about midnight, so I never went home—I slept out there on a cot at Press Site 39.

• **William Lucas**, director of program development, *Marshall Space Flight Center*: I was very uptight. We knew that there were thousands of parts that had to work or else we'd be in real trouble. And we knew that once we gave the ignition signal there was nothing more we could do. It had to go.

• **Buzz Aldrin**, lunar module pilot, *Apollo 11*: I was the last one in, so I was let off the elevator at a landing one stop below while [Neil Armstrong and Michael Collins] were taken up to the capsule. I was standing on the edge of this swing arm looking out at this rocket, and the [ocean] waves coming in quite a bit lower, and the sun gradually coming up, and it was really a very lonely and yet private, peaceful moment before getting into that wondrous white machine that was going to propel us off into history—we hoped.

• **Robert Sieck**, spacecraft test and launch operations engineer, *Kennedy Space Center*: Since I was the backup engineer, I was not out at the Cape. I could watch the launch with my wife and my 1-year-old daughter. The highway was absolute gridlock, and the cars and trucks weren't trying to move. **Everyone was there to watch history. The vendors were sold out of everything—no more T-shirts, caps, buttons or pins. People were pulling plugs of grass from the side of the road and stuffing them in zip-lock bags as souvenirs.**

• **Barbree**: We're in the countdown, and I felt this little tap on my shoulder. I turned around and looked up and it was Jimmy Stewart and his wife, Gloria. And he said, "Is it all right if we watch from here?" And I said, "Mr. Stewart, you watch from wherever you want to."

• **Morgan**: It's quite a physical experience, an Apollo launch, because it's such a slow liftoff—and then the shock waves hit you. We could feel it happening in the firing room because we had these shutters and they would flap back and forth, rattle, and the consoles would vibrate.

• **Lucas**: The stack of the Saturn V weighed a little over 6 million pounds, so we had about 7.5 million pounds of thrust at liftoff. When you see it lift off it looks like it will never clear the

tower. But as it burns away fuel, it gets faster—the weight at lift decreases, therefore it picks up speed. It ultimately gets up to about 24,000 mph to get into the lunar trajectory.

• **Barbree**: As soon as they had translunar injection, we all ran like scared rabbits to the airport, where we had a jet chartered for the news media. We flew directly to Houston.

COASTING TO THE MOON

Once the Saturn V cleared the tower, responsibility transferred from Launch Control at Cape Kennedy to Mission Control in Houston. After entering its second Earth orbit, the third stage reignited, sending Apollo 11 toward the moon.

• **Jack Garman**, group leader, program support group, *Apollo Guidance Software Section*: In the Mission Control Center, they had kind of a congressional layout—the flight director was the president; then there were various positions in the main control room that handled different functions, and each of them had staff support in adjoining rooms.

• **Gene Kranz**, flight director (FLIGHT), *White Team, Mission Control*: We always operated with four teams during the lunar missions. We did this to balance the training workload, and because shifts are pretty long so it gives 'em a break.

• **Steve Bales**, guidance officer (GUIDO), *White Team, Mission Control*: We were all in the 25- to 28-year-old range except for Gene, who was 35. **People who were drawn to NASA at the time were younger; it wasn't as if anybody had done this particular job before.** The crew, they were all 38, 39, 40—they seemed a lot older to us. Or at least to me, anyway.

• **Neil Armstrong**, commander, *Apollo 11*: I was 24 when I joined NACA—later NASA—and was given very challenging work both as a pilot and as an engineer in flight research. I was confident that men of that age could do the job. Additionally, this new Space Age required people who understood digital computers, and most of the people in that category were in their 20s.

• **Garman**: Nobody knew much about computers in those days—and nobody knew much about flying spacecraft either. If people thought, "Are a bunch of young kids gonna screw up this mission?" we never heard it.

• **Chris Kraft**, director of flight operations, *Mission Control*: On the way to the moon, you might say, "Well, that could be a pretty boring time." But that's not true. There were times when you had to do things with the fuel cells, when you had to get rid of the water in the system. You're making sure the thermal operation of the spacecraft is being done well. On Apollo it was called barbecue mode.

• **Hugh Blair-Smith**, software engineer for the *Apollo guidance computer, MIT Instrumentation Laboratory*: For the long three days from the Earth to the moon they had to keep

PHOTOGRAPHS BY APOLLO ARCHIVES (PREVIOUS SPREAD), KENNEDY SPACE CENTER (CONTROL ROOM)

Launch Control Center personnel rise to watch through a window as Apollo 11 lifts off from the pad, 3½ miles away. About 450 people work in the firing room during countdown, including instrumentation controller JoAnn Morgan (third row of consoles, second from left). "It's extremely intense work," Morgan says. "When you're going through the countdown and the launch you're very focused. Everything is preplanned—it's like a script in a play."



ANATOMY OF A MOONSHOT

The most remarkable thing about Apollo 11—considering the uncertainties of manned spaceflight and the mishaps that bedeviled NASA on previous and subsequent missions—was its nearly flawless execution, from liftoff to splashdown. “I had the sense that surely something would go awry sooner or later,” flight director Glynn Lunney says. “It was pretty much by the book.” Here are the critical events that had to go right, and what would have happened had they gone wrong.

BY JOE P. HASLER
DIAGRAM BY DOGO
AEROSPACE CONSULTANT:
DENNIS R. JENKINS, NASA

Launch (1) Five F-1 rocket engines fire 0.3 seconds apart to lessen astronaut-debilitating acoustic vibrations, and the Saturn launch vehicle slowly rises off Pad 39A at Cape Canaveral (then Cape Kennedy). Any engine failure during the 11 seconds it takes the spacecraft to creep past its launch tower could result in pad fallback or collision with the tower. “We had a contingency plan for everything we could think of,” propulsion engineer William Lucas says. “But if the problem was 100 feet off the ground, then that’s catastrophe.”

Pitch and Roll (2) Two miles off the pad, Saturn’s guidance computer puts Apollo 11 on the proper trajectory. Without precise execution, the craft will fly off-course at a velocity approaching 1500 mph. “During the launch phase there were three of us who had the abort switch,” H. David Reed, flight dynamics officer, says. “I had one because the trajectory could go before you could discuss it.” Loss of control would mean ejecting the crew capsule and destroying the rocket.

-
- 1. **Launch**
 - 2. **Pitch and Roll**
 - 3. **Translunar Injection**
 - 4. **Docking and Extraction:**
The CSM separates from the Saturn, then couples with the LM, removing it from the launch vehicle.
 - 16. **Command Module Separation:**
The CM sheds its service module before entry.
 - 17. **Entry**

Boosted by 7.5 million pounds of thrust, the Saturn V rocket thunders into the sky over Cape Kennedy on July 16, 1969.

Pullout Mission Guide



Translunar Injection (3)

After 1.5 Earth orbits, a 6-minute burn by the Saturn's third-stage engine sends Apollo 11 toward the moon at 24,000 mph. The engine has already provided Saturn's final push into space; some at NASA fear reignition in microgravity will fail, as it did on unmanned Apollo 6, because of trouble feeding free-floating propellants to the engine. Failure here would leave an alternate mission in Earth orbit as NASA's consolation.



Loss of Signal (6) Each lunar orbit takes Apollo 11 behind the moon, rendering it incommunicado with Mission Control in Houston for 45 minutes. Lacking the onboard navigation and computing power needed to target a return to Earth, the spacecraft receives targeting information from Houston before each loss of signal. If acquisition of signal fails when it emerges from the backside, the landing will be scrubbed and the crew will use that information to target a contingency burn home.

Lunar Orbit Insertion (7) After loss of signal, Apollo 11 fires its service propulsion engine in two burns to slow its momentum and enter lunar orbit. The first lasts 6 minutes and places the craft in an initial orbit of 170 x 61 nautical miles. A second burn lasts just 17 seconds and eases Apollo 11 into an orbit of 66 x 54 nautical miles, ideal for lunar module separation and powered descent. Using two burns reduces the chance of an overburn, which might crash the spacecraft into the lunar surface.

Saturn Third Stage (S-IVB)
Lunar Module (LM)
Command Module (CM)
Service Module (SM)

Powered Descent (9)

As the LM begins powered descent, communication with Houston drops in and out. Then, 7.5 miles from the surface, two program alarms sound and continue intermittently for much of the landing. Computer experts in Houston assure the crew it is safe to continue. If the ground calls for abort, Neil Armstrong would throttle up the descent engine and return the LM to orbit for retrieval by the CSM. "He would have been in a different orbit, so it would be a complicated rendezvous," says John Llewellyn, retrofire officer. "But we would never leave a guy in orbit—ever. That was a rule."

Entry (17) After jettisoning the service module, the CM enters the atmosphere at a velocity approaching 25,000 mph and an entry angle of minus 6.488 degrees. "The velocity of entry and the flight-path angle had to be very closely controlled—within a tenth of a degree," says Chris Kraft, director of flight operations. Safe splashdown requires successful deployment of two of the craft's three parachutes. On Apollo 15, one failed, but all of Apollo 11's chutes deploy, gently dropping the CM in the Pacific, where Navy recovery crews await.



5. **Translunar Coast:**
Apollo 11's three-day,
240,000-mile journey to
the moon.

6. Loss of Signal

15. **Trans-Earth Coast:**
Apollo 11's return
voyage to Earth.

13. **Lunar Module Jettison:**
LM detaches from CSM
and is left in lunar orbit.

8. **Lunar Module Separation:**
LM undocks from CSM
to prepare for descent.

11. Ascent

10. Final Landing
Phase

Final Landing

Phase (10) Just 350 feet above the moon, Armstrong realizes the autopilot is guiding the LM toward an enormous crater surrounded by boulders and begins to steer the craft downrange. This maneuver nearly exhausts his fuel supply. "We wanted to complete the mission if we possibly could, so we stretched it right down to the very bottom of the tank," LM control officer Bob Carlton says. Armstrong risks entering "dead man's curve," where, if fuel reserves run out, the LM is still too high to safely crash-land, and will fall too quickly to successfully execute an abort.

Ascent (11) After 22 hours on the moon, the LM must fire its ascent engine. No abort contingency exists. Flight director Glynn Lunney: "The rocket engine had to work in order for us to get off the surface of the moon and up into an orbit where we could rendezvous with the command ship." If the ascent stage reaches an altitude of 11.5 miles, the CSM can descend for an emergency rescue, but failure to attain even that low lunar orbit makes recovery impossible, and the LM will fall back to the lunar surface.

LM Ascent Stage
LM Descent Stage

"These events got your heart racing, because they had to work. And they always seemed to work." – SY LIEBERGOT, MISSION CONTROL

Buzz Aldrin explores the lunar surface.

7. Lunar Orbit Insertion

12. Rendezvous

9. Powered Descent

BACKSIDE OF THE MOON

14. **Trans-Earth Injection:** The CSM engine fires, sending Apollo 11 back to Earth.

Rendezvous (12)

Having reached lunar orbit, the LM executes a series of thruster burns that initially put it into concentric orbit with the CSM, then slow the spacecraft's velocity to prepare for docking. If the LM propulsion system fails at any point during the 4-hour procedure, the CSM can execute a "mirror-image maneuver" and drop back to retrieve it.

NOT TO SCALE: Orbital trajectories exaggerated and simplified for clarity.

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The powered descent was the most challenging segment of the flight. The systems were heavily loaded, the margins were slim, and this would be the first time that the entire descent strategy would be fully tested.

— NEIL ARMSTRONG, COMMANDER, APOLLO 11

the spacecraft rotating just like a pig on a spit so the sun wouldn't be concentrated on any one side.

• **H. David Reed**, *flight dynamics officer (FIDO), Green Team, Mission Control*: There's a lot of outgassing from the service module—venting stuff overboard. That will change the trajectory. If you're going 238,000 miles out, and walk up to the side [of the craft] and even blow on it, that slight movement will be multiplied by a lever 238,000 miles long.

• **Hal Loden**, *lunar module control officer (CONTROL), Black Team, Mission Control*: You don't want to hit the moon, but when you do miss it, you want to miss it at the right altitude and inclination so that you'll go into orbit.

• **Reed**: So we'll track it for awhile, notice the trajectory is changing and make a midcourse correction.

• **John Llewellyn**, *retrofire officer (RETRO), Green Team, Mission Control*: In those days, we didn't have GPS and all that stuff. The crew didn't have any of that either. They had almost the same thing Columbus had—a sextant and a star field.

• **Aldrin**: Because of the significance of the mission, we didn't want to have any distractions in case we had other distractions that really required our attention. We had them take any extraneous experiments off the outbound leg, so we could concentrate on the midcourse corrections, the platform alignments, the reports, sleep and meals—things we really had to be doing.

• **Doug Ward**, *NASA public affairs officer*: In Mercury and Gemini nothing was released live—not even the air to ground. But once they got 10 or 20 thousand miles from Earth [on Apollo 8] they were in continuous contact. From that point on, all of the communication was live.

• **Armstrong**: In all of science fiction—Jules Verne, H.G. Wells and others—no writer had ever envisaged that lunar explorers would be in communication with people on Earth or, even more surprisingly, be able to transmit still pictures or moving images back to Earth. So we understood that was an important component of our flight objectives.

JULY 20, 1969—LANDING DAY

A pair of lunar orbit insertion burns put Apollo 11 into orbit around the moon. On the eleventh revolution, the White Team assumed the consoles in preparation for descent.

• **Kranz**: I remember very clearly when I left the house.

I had my fresh haircut, and my wife had packed me a sack lunch that was enough for three shifts of people. As I arrived at my parking spot at [the Manned Space Flight Center], I realized I didn't remember driving through Clear Lake, or anything else. I was so

preoccupied I was on autopilot.

• **Bales**: When we came in that morning, the lunar module was dead. We had to power it up, get the thing aligned and checked out. In the simulations, that's where we'd always had the biggest difficulty, really. We had never completed without some major problem—and I don't know if we ever completed successfully in training—what we called a power-up and initialization of everything, and then gone ahead and done a landing.

• **Sy Liebergot**, *electrical, environmental and communications officer (EECOM), Black Team, Mission Control*: We had both the descent team and the ascent team in the Control Center at the same time. If we had to abort and get off the lunar surface, the descent guys would move off the console and we ascent guys would move into position to perform the part of the mission we were specially trained for.

• **Kranz**: I indicated that whatever decisions they'd make that day, I'd stand behind them—that we came into the room as a team, and we'd leave as a team.

• **Garman**: It got very, very real as [the spacecraft] went around the moon and got ready to undock. In fact, I remember vividly them locking down the Control Center. The guards were not to let anybody in or anybody out.

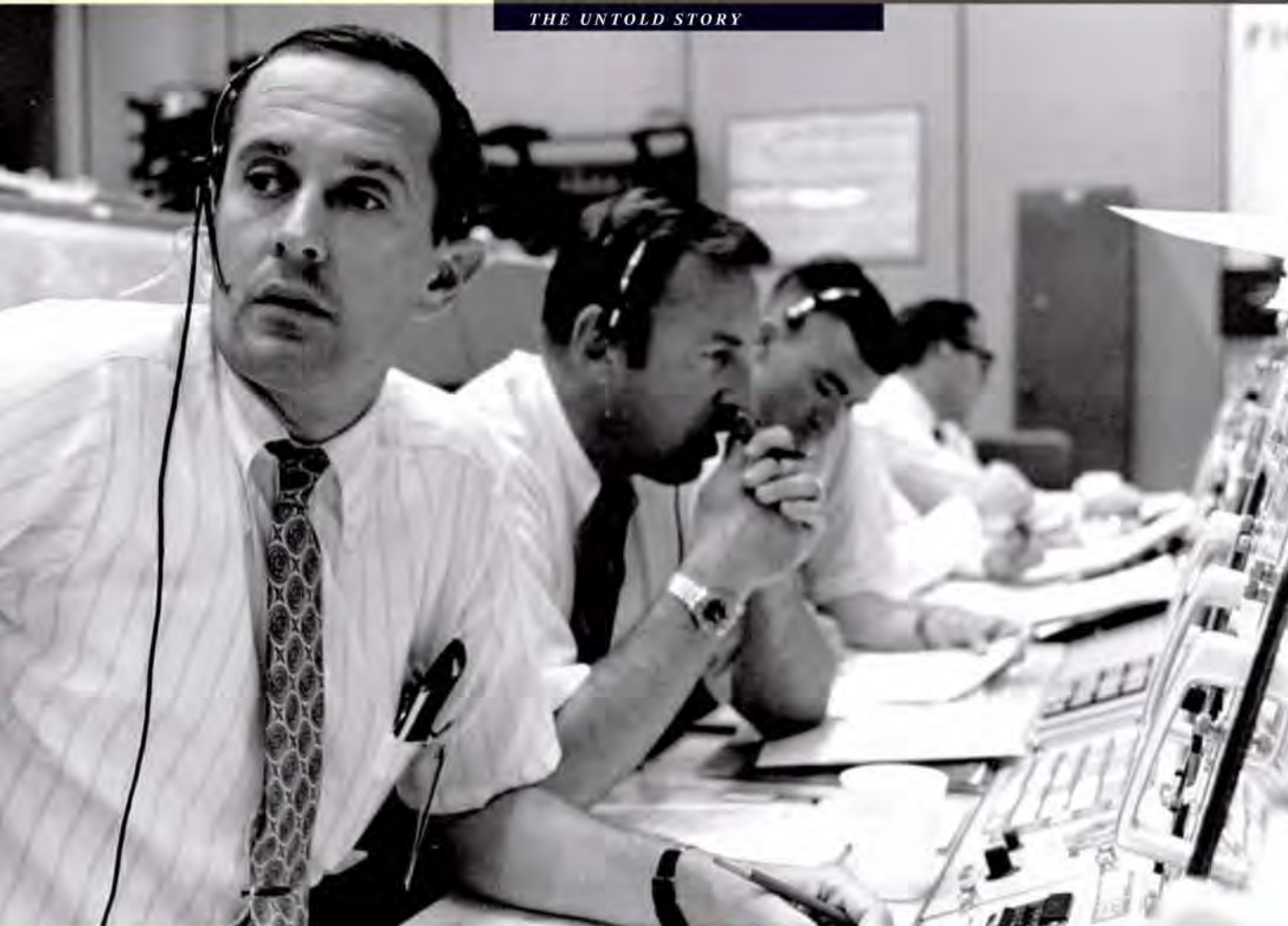
Michael Collins in the command/service module performed a separation maneuver. Half a revolution later, Neil Armstrong and Buzz Aldrin, in the lunar module, executed a descent orbit insertion burn, which allowed gravity to begin to pull the vehicle toward the lunar surface.

• **Aldrin**: At that point we're maneuvering to go backwards, engine first and facedown, in the attitude where we're going to start the powered descent.

• **Joe Gavin**, *director, Lunar Module Program, Grumman Aerospace Corporation*: The whole thing was tense, because we were basically aircraft designers. In the aircraft business you always flight tested something before you delivered it. In the case of the lunar module, you couldn't flight test it. Every launch was a brand-new vehicle.

• **Ward**: All the way down we kept losing communications and it would come back and we'd lose it again. I was right on the edge of my seat thinking, "You know, we're gonna abort for that."

• **Kranz**: We gave 'em the go for the start of powered descent and, doggone it, right at the time the engines started



Astronauts Charlie Duke, James Lovell and Fred Haise in Mission Control. Only astronauts on the ground communicated with those in the craft. "The thought was that a crewman in Mission Control would have a better understanding of what the crew was experiencing," Duke says.

we lost data again. We picked it up momentarily thereafter, and very shortly after that a guidance officer indicated we had some trajectory perturbation. In fact, he said, "We're halfway to our abort limit." Well, that is sort of sporty before you even start down to the surface.

• **Aldrin:** We're about a minute, maybe 2 minutes, into powered descent, facedown, and Neil says to me, and the Earth, "I think we're gonna be a little long." I said to myself, how in the world can he really, at this point, tell that we're gonna be a little long? But sure enough, we were.

• **Armstrong:** Prior to igniting the lunar module's descent engine to initiate the trajectory toward the lunar surface, I had been timing our angular rate over the craters on the surface below to calculate our altitude. I noted that, at ignition, we were somewhat west of our intended starting location. I inferred that our entire trajectory and landing point would be somewhat west of our planned landing spot.

• **Aldrin:** I've learned that whenever Neil says anything, you'd better pay attention because there's good meaning to it.

• **Bales:** The lunar module could do a lot of things independently, but it had to rely on people on the ground to tell the computer where it was starting on its landing position. On the backside of the moon there had been some venting—some perturbations unknown to us. The time we gave them to light the engine was about 4 or 5 seconds late.

• **Aldrin:** There comes a point in the checklist where we yaw around so that we're faceup, then pitch forward a bit before we throttle down. The purpose of doing that is to get the landing radar to lock onto the surface at about 30,000 feet.



PM photographed Neil Armstrong's gloves and spacesuit at the National Air and Space Museum's Garber facility in Suitland, Md. "You couldn't go through all that trouble to put a guy up there on the moon and make him immobile," says Homer Reihm, chief project engineer for the Apollo spacesuit at ILC Industries. "The Apollo [suit] was the first real walking spacesuit." It also had to withstand lunar surface temperatures ranging from minus 250 F to 250 F. Concern about dust contamination and weight meant Armstrong's boots were left on the moon.

PHOTOGRAPHS BY CHRISTOPHER GRIFFITH





Flight directors Gene Kranz, Glynn Lunney and Cliff Charlesworth (top, left to right) watch as the crew begins to explore the moon. "We were all engineers," Lunney says. "Because we were so busy thinking through what we were doing, and doing it, we didn't have much time to get emotional about it." Apollo 11 astronauts Buzz Aldrin and Neil Armstrong (bottom, left to right) photograph each other in the lunar lander before (Aldrin) and after (Armstrong) their moonwalk.



• **Bales:** As soon as it locked on, the radar saw that we were going a little bit fast in radial velocity and corrected the computer. At the time, I thought our worst problem was over. It turned out our worst problem was just about to start.

• **Aldrin:** We got the first 1202 alarm. So we look at each other, and we know it's in the guidance and navigation dictionary, but rather than try and get it out while the module is making a powered descent, Neil asked them what's the reading on the 1202 alarm. Then we got a 1201.

• **Charlie Duke, astronaut, capsule communicator (CAPCOM), White Team, Mission Control:** I was shocked. Actually, "stunned" is a better word. I started reaching for my guidance and navigation checklist to see what a 1201 and a 1202 was. And, of course, Steve Bales knew immediately and didn't hesitate very long to say, "We're go on those alarms, flight."

• **Bales:** I barely heard him. If you listen to the [voice] loops, there's a lot going on. And then finally the data comes in and we see the 1201, and Jack [Garman] is yelling—I mean, almost literally yelling, "It's okay! It's okay, as long as it doesn't keep going on!"

• **Garman:** There was a team of flight controllers whose duty it was to come up with simulation profiles that train the flight controllers and astronauts together to survive and fix things. At one point, they had asked me to come up with a failure that was totally software-related. I did that months earlier, and they stuck that in during one of the simulations.

• **Kranz:** Steve [Bales] had never seen this before. During the simulation, they had an abort, which was his call.

• **Bales:** There's a general rule in flight control: If you don't know what to do, don't do anything. The problem is, in the middle of a lunar landing, not doing anything is not an option.

• **Garman:** Gene Kranz sat us all down and said, "I want you to figure out every possible alarm code that can happen in flight so that we're prepared." In those days, there was no such thing as desktop computers. So I wrote down all the alarm codes on a sheet of grid paper, with crib notes on what they meant and what our response should be. And I stuck it under the plexiglass of the console I was to sit at. And, lo and behold, one of them—well, a couple of them—popped up during the actual landing.

• **Don Eyles, software engineer, lunar module guidance computer, MIT Instrumentation Laboratory:** What led to [the alarms] was an obscure mismatch deep in the electronics—two signals that should have been locked together in phase were only locked together in frequency. That hardware glitch involved the rendezvous radar, which really wasn't needed during the descent to the moon.

• **Aldrin:** I left it on. That turned out to be the main cause, and maybe the cause, of the program alarms.

• **Eyles:** Based on a random-phase relationship between those two signals, the rendezvous radar electronics were sending pulses to the computer at a very high rate.

• **Ward:** The computer was simply saying, "Hey, I've got more than I can handle but I'm gonna do the important things, so don't worry about it."

• **Garman:** The problem is that those program alarms set off what is called the "master caution and warning," which is red lights and very large klaxon sounds—if you've seen submarine movies, kind of like the klaxon that goes off when they say, "Dive! Dive!" And as I gathered from after-flight readings, the heart rates for Neil Armstrong and Buzz Aldrin went up just a bit.

• **Armstrong:** The powered descent was the most challenging segment of the flight. The systems were heavily loaded, the margins were slim, and this would be the first time that the entire descent strategy would be fully tested. A decade earlier, while I was flying in the X-15 program, we learned, surprisingly, that all the pilots, while flying the X-15, had heart rates between 145 and 185. It reflected the mental intensity appropriate for a challenging situation. The Apollo data seemed to correlate well with our prior experience.

• **Duke:** I didn't notice anything panicky, any tension at all in them. We just kept feeding them the information, trying to be as professional about it as possible. I don't think I was relaying any anxiousness in my voice—I tried not to, anyway—but tension was building.

• **Aldrin:** As long as you've got communication, Houston knows what [the problem] is, and they have more information, so they're going to be the ones that call the shots.

• **Liebergot:** We weren't exhaling, but very businesslike. And that's not to say the job was just ho-hum; it was not. It's that we, with hearts racing, did our job.

• **Eyles:** The final landing phase was the point where the astronauts took over semimanually to maneuver the spacecraft like a helicopter. When I say semimanually, I mean that the automatic system was controlling the throttle to maintain a commanded descent rate while the astronaut commanded the attitude of the spacecraft in order to scoot along the surface in whatever direction he needed to go.

• **Bruce McCandless, astronaut (CAPCOM), Green Team, Mission Control:** Neil was flying, looking for a boulder-free spot. It's fair to say people were holding their breath. But Neil had a considerable amount of experience in the lunar-module simulator and in the lunar-landing research training vehicle.

• **Armstrong:** Every flying machine has its own unique characteristics, some good, some not so good. Pilots naturally fly the craft in such a manner as to take advantage of its good characteristics and avoid the areas where it is not so good. In the case of the lunar module, surprisingly, it flew

I took my headset off, which is what you do if you don't want anybody to hear what you are about to say, and told Gene [Kranz], We have a problem: We do not know where the hell they are. — H. DAVID REED, FLIGHT DYNAMICS OFFICER, MISSION CONTROL

much more smoothly than I had expected based on all the simulator work we had done. It was a welcome surprise.

• **Bales:** There wasn't a lot being said, but we had a lot of data. I was thinking, "What in the bloody heck is going on?" Normally, in the simulations, once [Armstrong] got on a path to come down, he killed all the velocities but altitude rate and pretty much just came straight down. But he wasn't. He had a forward velocity of 20 feet per second. And, of course, that was eating up fuel.

• **Kranz:** We got what we call "low level" in the propellant tank. Once we got that indication, we knew we'd have roughly 120 seconds of propellant remaining at a hover throttle setting.

• **Bob Carlton, lunar module control officer (CONTROL), White Team, Mission Control:** We had never seen that light, never expected to see it. In all of the sims, we had so much margin, that wasn't normally a factor.

• **Garman:** At that point there was nothing the ground could do except watch. It became a spectator activity. The tension went up noticeably. Very noticeably.

• **Duke:** Everybody was glued to his monitor.

• **Carlton:** I had a stopwatch. I'm looking at it, and at the same time I'm looking at the altitude, and I can see it's still a long way down. I didn't know it, but the guys were flying over a crater. We call up 30 seconds. I'm thinking there's no way we're going to make it.

• **Kranz:** I'm a Catholic, and in the flight director business, you want all the help you can get.

• **Carlton:** When the engine shut down, I had 18 seconds to the point where we would have aborted.

• **McCandless:** I was in the control center as a spectator, sitting right next to Charlie Duke, who was the capcom. Once Neil came back with his transmission, "Tranquility Base here. The Eagle has landed," in spite of the earlier admonitions to maintain decorum, we burst into spontaneous cheers and applause.

• **Duke:** As you can hear in the transcript, I was so excited, "tranquility" came out, "twank." I caught myself before I finished the word, "Twank—I mean, Tranquility. Roger, Tranquility, we copy you down."

• **Ward:** Kranz immediately got on the loop and said, "Everybody settle down. Settle down. We've got some critical calls to make, and we've got to focus on what's coming up here."

But in the meantime we could hear this roar from the viewing room behind us. All of the politicians and top managers and astronaut families and so on were back there behind the glass.

• **Aldrin:** It was certainly momentous, but there were no trumpets blowing or cymbals crashing. We're there, we're

two guys, and we're not the yippee type. We see something, absorb it, think about it and that's it, accept the way it is.

LUNAR EXPLORATION

After checking the spacecraft's systems, Mission Control confirmed it was safe to stay on the lunar surface. The Black Team moved into position until the crew was ready to exit the craft—when the Green Team would take over.

• **McCandless:** After they were given the "stay" call and shut down lunar-module systems, I headed for home, which was about 10 minutes away, to get a bite of dinner.

• **Ward:** The original plan was that they weren't going to get out of the lunar module until the next day. They were going to get 8 hours of sleep and the next quote-unquote morning go do the first extravehicular activity.

• **McCandless:** But when I was pulling into the driveway, my wife came running out waving her arms. "They can't sleep! Go back!" So I turned around.

• **Milt Windler, flight director (FLIGHT), Black Team, Mission Control:** It was a pretty easy decision. You probably can't stop them, so why not go ahead and do it? Plus, we were all ready to get on the moon, too.

• **Don Beattie, program manager, Apollo Lunar Surface Experiments:** One scientist had projected that when the lunar module landed it would disappear into levitated dust. Even though we landed the Surveyor spacecraft successfully, that was a real concern. Another was that the dust would be pyrophoric—that when they opened the cabin of the lunar module, oxygen would react with dust and explode. There was no way we could be sure until the guys opened up the door and the oxygen flowed out.

• **McCandless:** They depressurized the lunar module, opened the hatch and Neil came down the ladder. There was a crude black-and-white TV camera, which transmitted images along the lines of a white blob going down some sort of inclined structure. I remarked, "Okay, Neil, we see you now, we've got you on TV."

• **Ward:** I was very conscious of the fact that what the crew said was extremely important historically. The commentator stepped on a foot switch that interrupted the air to ground, so anytime we talked it obliterated whatever the crew was saying.

▪ **Barbree:** He gets to the bottom of the stairs, takes a step on the moon to make sure he can, steps back up and says, "That's one small step for [a] man, one giant leap for mankind." *

▪ **McCandless:** The first order of business was collecting a contingency sample. Neil was supposed to scoop up whatever was near his feet, the first thing that was handy, so that in the event of an emergency they would have at least something to show for having been there.

▪ **Beattie:** The bulk sample had a different purpose—to make sure that we got a very wide variety of material.

▪ **Chuck Berry, chief flight surgeon, NASA:** We were concerned about the metabolic cost of working in the bulky suit. The best way to monitor them on the lunar surface turned out to be the change in water temperature in the water-cooled undergarments. We had sensors to measure that, and we could then sort of gauge how far they could go.

▪ **Armstrong:** On the lunar surface we had both the 16-mm movie camera and the television camera in fixed positions so our surface activities would not be slowed by camera position and setting requirements.

▪ **Harrison H. Schmitt, astronaut, mission scientist for Apollo 11:** Once an extravehicular activity starts the crew is going to move along the timeline and get as much done as they possibly can. Buzz Aldrin was talking about a lot of things that he was checking, like mobility.

▪ **Aldrin:** After the flag was up, I made a point of being in front of the camera just demonstrating different means of moving around.

▪ **Schmitt:** While he was doing that we were all wondering what Neil was doing. Well, Neil was deploying a small set of experiments as well as collecting this very fine and diverse group of rocks and soil. Not only did he get a very wide distribution, but he also thought the box looked a little empty, so at the last minute he filled it with just the dirt, so to speak—what we call the lunar regolith. That sample turned out to be the best, most comprehensive sample of the lunar regolith that was ever taken on any of the Apollo missions.

* Armstrong's famous words have been the subject of much speculation. Lunar surface communications were voice-activated and subject to interference, so a vowel could easily have been dropped. Armstrong confirmed to PM that he did articulate the "a."



Astronauts Neil Armstrong, Michael Collins and Buzz Aldrin (left to right) inside the Mobile Quarantine Facility on the USS Hornet. "I did not consider our work done until we were safely aboard the aircraft carrier," Armstrong says.

BLASTING OFF THE SURFACE

After a 22-hour stay on the moon, Aldrin and Armstrong prepared to fire the ascent stage of the lunar module to launch back into lunar orbit.

• **Reed:** My job was to come in prior to ascent, find out where they landed, and use that information to compute their launch time. Then we'd upload that to the crew. When I called the tracking people, the guy at the other end of the line said, "Dave, take your pick. I've got five different landing sites." He said we know where the lunar module thinks it landed, where the backup guidance system thinks it landed, where the radars on the ground tracked them, where we targeted them, and now we've got the geologists saying a different location.

• **McCandless:** In the meantime, Mike Collins in the command module orbiting overhead was tasked to use a telescope to try to locate the lunar module. Poor guy never really got any sleep for trying to find it.

• **Reed:** I took my headset off, which is what you do if you don't want anybody to hear what you are about to say, and told Gene [Kranz], "We have a problem: We do not know where the hell they are." There was only one way to figure that out. The capcom woke Buzz Aldrin one rev early to do a rendezvous radar check. Because I knew where the command module was and I had the vectors that allowed me to

CONTINUED ON PAGE 128

STRAIGHT OUTTA ASPEN

A SUMMER ROAD TRIP DOESN'T NEED PAVEMENT OR

by Ezra Dyer



EVEN MODERN TRANSPORTATION. WE TACKLE COLORADO'S DUSTY MOUNTAIN TRAILS IN A REBUILT, RESTORED AND VERY RUGGED ICON FJ40—AN OLD-SCHOOL 4WD ADVENTURE IN THE HEART OF THE ROCKIES.



The capable Icon makes short work of Imogene Pass. The trusty companion took us on a four-day adventure in Colorado's Rockies.

WE'RE BOUNCING STRAIGHT

for the edge of a cliff. My wife, Heather, is in the shotgun seat, her right foot reflexively reaching out to press her own phantom brake pedal as blue sky fills the windshield. Adrenaline, about 10 Red Bulls' worth, courses into my system as I lean on the brakes and wrestle the steering wheel to the right, until the passenger-side mirror is nearly grazing the sheer rock wall that defines one side of the trail. Better to hug the cliff, because the other side of the trail is defined by abrupt, airy nothingness. I downshift a gear in low range and manage to negotiate the vertigo-inducing switchbacks of Tomboy Road as we make our way from 13,114-foot Imogene Pass down to 8750-foot Telluride. Locals characterize Tomboy as an intermediate trail, but, of course, that presumes you don't fall off it.

If you've got five days to spend in a single state, and you want to experience the best roads, the best views and the most charismatic towns, plot a route through the Colorado Rockies from Durango up to Boulder. You'll find 14,000-foot mountain peaks littered with postcard vistas and draped with the alpine roads you dream about during your daily commute. I enlist Heather to help an adventure that takes in some legendary towns—Telluride, Crested Butte, Aspen. In these places you can escape civilization—and still find a place to eat a nice steak if you roll in at 9 pm.

I have a good idea where I'm going, because a few days earlier I drove from Telluride to Lake City—50 miles, more or less—almost entirely

Photographs by Matt Gunther

POPULARMECHANICS.COM | JUNE 2009 85

4WD Buildup Tips Inside



off-road, in a Hummer H3T Alpha. With less than 200 miles to cover on any single day, there should be plenty of time for hiking, mountain biking, fishing and off-roading. That last activity helps dictate the choice of vehicle for this endeavor. What I want is a cross between a Jeep Wrangler Rubicon and a Toyota Prius, but no new vehicle comes close to combining that degree of off-road acumen and fuel-miser efficiency. There is another option, though: revising the past.

ROCKHOUND

ANYONE WHO'S DRIVEN A CLASSIC TOYOTA FJ40

Land Cruiser would praise its utilitarian, go-anywhere talents, but in terms of livability, an old FJ is a Massey Ferguson tractor crossed with an Iron Maiden. TLC, a small company based in California, specializes in reimagining the FJ as the Icon—essentially an original FJ40 that's been stripped down to its bare frame and rebuilt with modern amenities and cool details like handcrafted, engraved and enameled stainless-steel dash knobs. A new drivetrain is part of the package, and TLC now offers a four-cylinder turbodiesel that allows the Icon to average between 22 and 28 mpg. Not bad for a vehicle equipped with 33-inch tires, locking differentials and a hefty winch bumper. The diesel also runs on biofuel, should we happen to come across any of Willie Nelson's filling stations.

This particular Icon diesel is loaded with toys—heated seats, a thumping stereo and a Power Tank CO₂ reservoir for airing up the tires. Despite the vehicle's amenities and six-figure price, the driving experience is still retro. Wind, road and engine noise barge in through the soft-top, the five-speed shifter has longer throws than an Olympic javelin competition, and the steering is disarmingly slow on these serpentine roads. And yet the squeaks, rattles and groans of an old vehicle, the telltale complaints of calcified bushings and rotten seals, are entirely absent. It may be retro, but it's definitely not old.

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Mild Buildup



Moderate Buildup



Extreme Buildup



Vehicle

Newer 4WDs like the Nissan Xterra have a smooth-riding independent front suspension. They can tackle easy trails with minimal modifications and still maintain on-pavement road manners.

Trucks with a live-axle front suspension, like 1973–1991 Chevy Suburbans or comparable K-Series pickups, make tough platforms. These vehicles can be bought and built inexpensively.

A classic two-door Jeep CJ or Wrangler is a perfect blank canvas to build a hardcore 4x4. Jeep parts are plentiful, and there's a deep knowledge base for what works—and what doesn't.

Engine

Don't void the warranty. Reusable air filters improve filtration and breathing. When combined with an exhaust system that installs behind the catalytic converter, these safe upgrades can yield up to 10 hp.

Worn-out V8? Swap in a factory crate motor for reliability and increased power. Powerful motors can break parts. So plan to upgrade the drivetrain if you add serious horsepower.

A V8 or diesel conversion delivers the torque to turn large tires. Upgrade to larger heavy-duty-truck-spec axles, transmissions and transfer cases, which are often needed to handle the stress.

Suspension

Maintain stock height to preserve the factory handling and stability. Aftermarket off-road shocks can offer better control over rough terrain. The tradeoff? A firmer ride on the street.

A modest 2- to 4-inch taller suspension system and longer shocks create room for larger tires, increase axle articulation and boost capability. But systems with more lift typically ride rougher.

Expensive coil-link systems can provide incredible suspension flex for serious rock crawling. They offer excellent ride quality on the road too.

Tires/Differentials

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To clear boulders, opt for tires size 37 inches and up. Suspension articulation helps maintain traction. But the toughest trails require a locking differential—in both axles—for true 4WD.

Protection/Recovery

Aluminum skidplates underneath help protect drivetrain components. A tow hook or clevis shackle bolted securely to the frame is essential for snatch-strap or winch recovery.

A winch can extricate your truck from the worst-case-scenario stuck. Electric winches are expensive but worthy investments—especially when four-wheelers travel alone.

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The Right Stuff

Goodyear's aggressive new Wrangler MT/R mud tire has a Kevlar sidewall to reduce punctures and a rim protector to guard against wheel damage in all terrain. The MT/R comes in 30 sizes.

Warn's PowerPlant Dual Force HP is two tools in one: a 9500-pound, single-line pull winch and an air compressor to inflate tires on the trail or run impact tools. Auxiliary air tanks are available.

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After a hearty breakfast in Crested Butte, Heather eyes the grumbling orange truck outside the diner and asks, "Why'd you leave it running?" I produce the ignition key



A mishap with the mountain bikes means every latch and lever on this bike rack (above) gets an extra half twist of torque from here on out. Who needs a restaurant with fancy-pants tables, chairs and plates—this is a road trip. There's nothing like convenience-store microwave tamales for a perfectly balanced meal (right). Below: Telluride's Wild West.



off-road, in a Hummer H3T Alpha. With less than 200 miles to cover on any single day, there should be plenty of time for hiking, mountain biking, fishing and off-roading. That last activity helps dictate the choice of vehicle for this endeavor. What I want is a cross between a Jeep Wrangler Rubicon and a Toyota Prius, but no new vehicle comes close to combining that degree of off-road acumen and fuel-miser efficiency. There is another option, though: revising the past.

ROCKHOUND

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The Icon's winch isn't needed on the way up to Imogene Pass—which is fortunate, because above tree line there aren't many anchor points.





Barely 20 minutes outside Boulder, and in shin-deep water, the author hooks a monster while fly fishing—and promptly releases it to go breed more leviathans of the deep.

from my pocket and explain that there really wasn't much choice. The ignition switch is shorted out. See, production Icons get break-in mileage to expose any kinks or faulty parts, but on this brand-new example, we're performing the shakedown in the field, as it were. And we've got a kink on our hands. Since I'm not sure whether the switch will still crank the starter, I make a game-time decision: We're not shutting this thing down till we get to Aspen. And thus, our stroll around a pristine mountain lake is accompanied by the persistent growl of the idling Icon. The hills are alive with the sound of compression ignition.

As I fill up at a local gas station, I ask the attendant about a trail someone mentioned that connects Crested Butte and Aspen. "Oh yeah, the Schofield Pass," he says. "That trail is mega-gnar." Then, deciding he might've under-gnarred his original estimate, he adds, "Mega-mega gnar." He eyes the Icon sitting at the pumps. "That thing would make it, but if you put a wheel wrong, you fall 40 feet into the river." I ask if there is perhaps a kinder alternative for this \$122,000 truck that does not belong to me, a trail rated single-gnar or less, and he recommends another unpaved way called the Kebler Pass. The Kebler Pass is more like a dirt road than a

trail, and I air down the Icon's tires to take the edge off the stutter bumps. This smooths out the ride nicely, and I make a conscious decision to avoid telling Heather that we could have had a much nicer drive up Imogene Pass if I'd thought of this sooner. The aspen forest makes for a beautiful backdrop, and the woods are teeming with life—including, oddly, cows. Heather notes that cows are normal and trees are normal, but put some cows among the trees and suddenly you've got a strange and exotic tableau.

A few hours later we're in Aspen, and I pull into the parking lot of the Gant Hotel, press my right foot on the brake and pop the clutch with my left. The motor stalls, choking itself into silence for the first time in the past 7 hours. Now comes the real moment of truth: I turn the key to see if it'll start up again. The starter spins, the motor roars to life, and we're in business. After shutting down again, I disconnect the battery to keep the accessories from killing it overnight, but we have a viable strategy for continuing our trip. This is the benefit of older designs—things may go wrong, but it's a lot easier to devise work-arounds than it is in new cars. There are no OBD II trouble codes, no electronic security systems to go haywire. Bad ignition switch? Stall it out.

DAMAGE WAIVERS

AS WE WALK AROUND ASPEN, I NOTICE A POSTER advertising performers at a subterranean bar. "Hey, look," I say, "Ice Cube played at this place!" It seems unlikely that Ice Cube, of N.W.A fame and *Friday* movie stardom, would've played a little bar in Aspen, but there it is. "Look at the date," Heather says. "He didn't play there already, he's playing there tonight!" And that's how we ended up witnessing Ice Cube performing "Straight Outta Compton" live in Aspen. That's the kind of thing that could make for a good story later. Just like when you try to go mountain biking and your bike falls off the car rack at 50 mph.

About that: I thought everything was properly ratcheted down when we set off toward Woody Creek. The woman at the bike place told me that the late gonzo legend Hunter S. Thompson used to live near the trail, so I wanted to check it out, even if Thompson probably would've pistol-whipped me for wearing a helmet while riding a bicycle. He would have fully approved, however, of the carnage. As I hit an expansion joint on the highway, my bike bounces off the rack and begins a death cartwheel down the highway. Did I sign up for the damage waiver? I hope I signed up for the damage waiver.

When I return the bike, the shaggy dude at the counter buys my explanation for the large chunk of foam missing from the seat. "I took a digger," I say, gesturing to the road rash on the seat. "You sure did!" he agrees, and I depart before he can ponder how I trashed the seat without suffering so much as a scrape myself.

ALPINE ANGLER

BACK IN THE ICON, WE CLIMB OUT OF TOWN on Route 82, headed toward Independence Pass on the Continental Divide. The blacktop is smooth and mostly free of plow scars. Up here at 12,000 feet, on one of the highest paved roads in North America, they don't even bother to plow in winter—they just close the road and wait till spring. Once the 10-mile route thaws, it's a popular climb for road bikers touring the Sawatch Range.

The Icon's turbocharger is whistling, and I'm spinning the steering wheel like Mix Master Mike on the turntables, but as I pass a parade of Porsches going the other way, it's hard not to wish that I had a sports car right now. At the top, the Icon's riotous idle is suddenly drowned out by an otherworldly shriek. Over the ridge, making excellent time, comes a red Ferrari Enzo, one of only a few hundred or so on the planet. Judging by the smile plastered on the face of the lucky guy behind the wheel, we should all aspire to drive a red Enzo over Independence Pass before we die.

Soon, we're on Interstate 70 for the first time on the trip. I want to reach Boulder in time to set up a fishing trip tomorrow. So we forgo lunch in favor of that traveler's staple, jerky (with a side order of surprisingly good convenience-store tamales), and head down I-70 as fast as the Icon can carry us.

My seat-of-the-pants approach to scheduling means that no guides are available. But I don't even need to drive that far to find my own solitary place to fish. Barely 20 minutes after I leave the Kinsley Outfitters Orvis shop in Boulder I drop anchor. I inspect the fancifully named flies I bought and ponder which one to deploy for some epic trout slaying. I contemplate the Chernobyl Ant and the Elk Wing Caddis, but decide to try the Stimulator first.

I'm more of a shameless bait caster than a fly fisherman; still, I try to dance the fly on the water, because that seems like what a fly would do, right? But the water is only up to my shins, and I fail to see how there could be fish here. They'd have to be two-dimensional, and I'm pretty sure flounder are not indigenous to the Rockies. I'm ready to give up and



The Icon may be fully restored and brimming with bulletproof drivetrain componentry, but don't expect a Lexus experience inside.

try a new spot, but suddenly the fly is tugged underwater, and the slack goes out of the line. The fishing in Boulder Creek really must be pretty good, because I caught a fish. I let it go—so there's no evidence to contradict the hyperbole I conjure to describe my catch back at the hotel bar in Boulder. It was a creature of the deep, five rows of teeth, license plates in its belly.

The next morning brings the road-trip bummer: the realization that we're done driving to new places looking for new adventures. No more random Ice Cube concerts, unexpected fly-fishing mastery or rural Enzo sightings. No more challenges—the bike tumbling down the highway, the shorted ignition—followed by the exhilaration of a successful fix. And, I'm sad to say, no more Icon. While I initially missed the refinement of a modern car, over the course of the trip the FJ endeared itself. It took us from Durango to Boulder, up Imogene Pass, through the Crested Butte aspens and past the woodland bovines, its center console shut tight enough to prevent the smell of the ever-present beef jerky from permeating the interior. Besides all its crafty details, the Icon has the FJ40 charisma, an authenticity that only comes with a genuine four-decade pedigree. **PM**

OUR GEEKY PROJECT

3 FEET

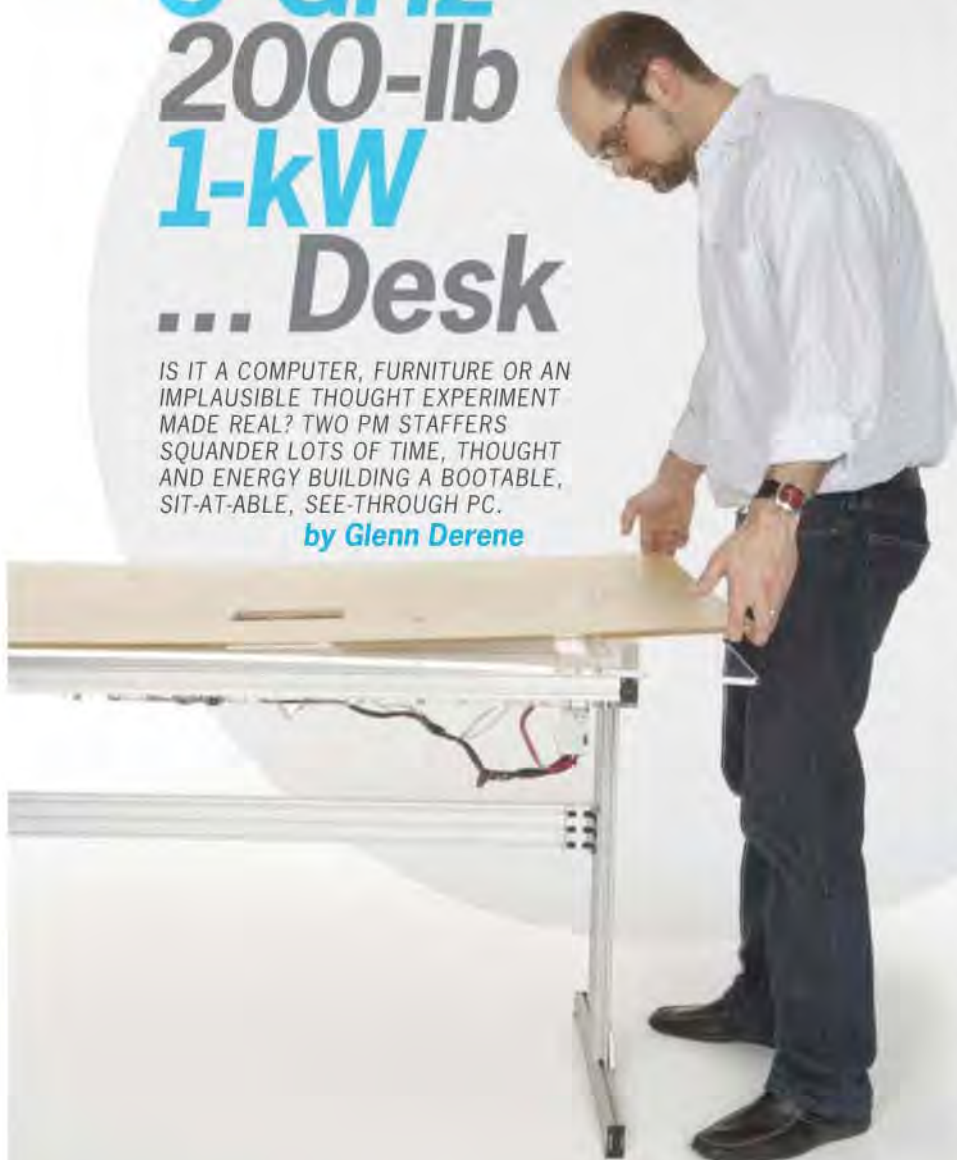
6 FEET



The Liquid-Cooled Quad-Core 3-GHz 200-lb 1-kW ... Desk

IS IT A COMPUTER, FURNITURE OR AN IMPLAUSIBLE THOUGHT EXPERIMENT MADE REAL? TWO PM STAFFERS SQUANDER LOTS OF TIME, THOUGHT AND ENERGY BUILDING A BOOTABLE, SIT-AT-ABLE, SEE-THROUGH PC.

by Glenn Derene



Step No. 1
Make Sure It Looks
Good on Paper



If science is the dispassionate pursuit of objective truth, then it stands to reason that *mad* science is the completely irrational pursuit of a nutty project that the rest of the world will never completely understand. POPULAR MECHANICS has a reverent journalistic respect for those who practice serious research. But on our own time, we like to dabble in the mad sciences.

Mad computer science, in particular, offers plenty of opportunity to practice our techno-alchemy in PM's labs. We have, in the past, created a series of "monster" PCs—labor-intensive masterpieces of technological complexity that were as wickedly powerful as they were unreliable and impractical. It takes a special kind of enthusiast to prefer such a machine over a store-bought PC with a two-year warranty.

I have an excuse. As PM's senior technology editor, it's part of my job to daydream Rube Goldbergian new designs for computers. My colleague, Anthony Verducci, however, is our digital imaging specialist. He is a master computer builder, but he is probably shirking his responsibilities (whatever those are), when he partners with me to help construct each new machine.

Our ideas often start out with a simple premise. About a year ago, I first came to Anthony with a plan to build a computer into the structure of a desk. A quick bit of brainstorming determined that there were essentially two ways to accomplish this: old-school (a classic oak executive's desk with components hidden behind false backs in the drawers); and new-school (transparent surfaces with components on display). The old-school approach was classy and definitely appealing (we won't

photographs by J Muckle

rule it out for the future), but the new-school approach was both less practical and more ostentatious, which made it our natural choice.

So we specced out a totally visible PC. The components—motherboard, graphics card, hard drives, etc.—would all be mounted beneath the surface of a transparent desk. Because an optical mouse would have trouble tracking on a clear surface, we imagined an integrated clear trackpad that would turn part of the desktop into a pointing device.

Our first thought was to make the desk out of tempered glass, but we decided that clear acrylic would be far easier to work with. Anthony had worked on previous computer builds with Dennis Leach, owner of Danger Den, an Oregon-based custom case and liquid-cooling company. Leach's shop has a computer-control laser that can cut and etch sheets of acrylic to create any shape or design imaginable. We e-mailed sketches back and forth to Leach for two months, planning out the placement of components, ventilation ducts and holes for tubes and wires.

Leach disabused us of some of our more fanciful design parameters—we had, for instance, requested that pathways for liquid cooling be routed through the acrylic desktop. A novel idea, if Leach could have pulled it off, but leaks would have been hard to fix, so he decided the coolant would have to flow through Tygon tubing.

While Danger Den was firing up its laser cutter, we submitted our touchpad design to Synaptics, a California company that makes trackpads in many laptops. We described a clear, USB-interface touchpad with an integrated proximity sensor that would light up the area whenever a hand approached. To our surprise, Synaptics' concept-prototyping crew said, "No problem." Within weeks, a working unit arrived at our labs. About a month later, a massive wooden box containing our 6-foot-wide, wing-shaped acrylic desk was delivered. And more deliveries kept coming, until we were surrounded by a sea of boxes and electronic parts. Now, the real work was about to start.

Step No. 2

Be Smart—Shop Twice, Buy Once



There are two important rules to grasp when designing a computer from scratch (and, yes, we've learned them the hard way, over a number of builds): First, everything is dependent on everything else. Our desk had to be built to fit its components, so we needed to pick the parts—motherboard, graphics card, etc.—before Danger Den could cut the acrylic. That meant no second-guessing just because a cooler part came out. Second, there's no manual—when something doesn't fit or doesn't work, you're on your own.

Step No. 3

Find a Good Hex Wrench



The aesthetic for our desk frame was strictly industrial. We used super-strong extruded aluminum rails with T-slots for affixing nuts and bolts—lots of bolts. The surfaces of our desk were pre-cut with holes for fasteners, wires and ventilation, allowing us to bolt the acrylic to the frame and components to the acrylic. Fortunately, Danger Den's Leach is a master of the acrylic arts, and his cuts matched our specs precisely.



The desk surface was constructed by Danger Den of two sandwiched, laser-cut layers of clear acrylic bolted to an aluminum frame.

A half-gallon of glycol runs through 15 feet of Tygon tubing and a radiator, cooling the processors.

Step No. 4

Darn! Order New Parts



- With all the components bolted down, our desk looked great. Then we tried connecting everything—and nothing fit (we should have paid more attention to Step 2). We had SATA cables that were too short and a power supply pointing the wrong way. Plus, our wacky layout required a custom 15-inch flexible PCI-E cable to connect our graphics card. Progress stopped while we placed a rush order to five online parts shops.

Step No. 5

Connect Everything, Add Glycol and Glitz



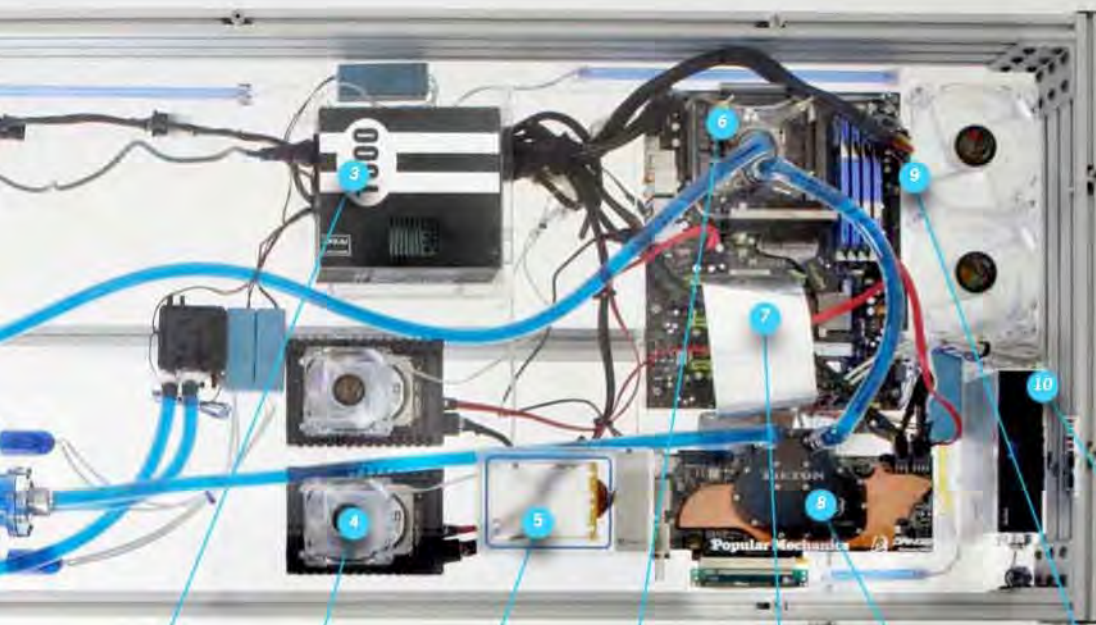
- Once all the wiring was in order, we started on the liquid-cooling system. Anthony painstakingly mounted water blocks to both the CPU and the graphics card, then planned out the flow of coolant. We ran tubes from the right side of the desk, where the chips are located, to the left side, where the radiator dissipates heat. At the suggestion of senior automotive editor Mike Allen, we mounted the coolant reservoir in a position that created a decorative waterfall of glycol without compromising the electronics. But the desk still wasn't gaudy enough for us. We needed lights—lots of lights. So we wired up seven glowing exhaust fans and six blue neon bars, which quickly overloaded our 850-watt power supply. That required an upgrade to a kilowatt beastie from Antec.

Step No. 6

We're Done. Wait—Okay, Now We're Done



- We locked down the clear acrylic top, installed the Synaptics touchpad, set up a 27-inch Dell UltraSharp monitor—and then spent a week futilely trying to install a beta version of Microsoft's Windows 7 operating system. We troubleshooted the system until we found the problem: our fancy-pants PCI-E cable. Another rush order to a specialty parts shop fixed the problem with a new cable. Finally, our lab was filled with the neon-blue glow of success. We had willed our digital creation into being.



To support our Times Square lighting, we used an Antec TruePower Quattro kilowatt power supply.

Two 300-GB 10,000-rpm VelociRaptor hard drives handle storage.

Synaptics engineered us this one-of-a-kind, flush-mounted touchpad with an integrated proximity sensor and light.

At the heart of our system is XFX's 790i Ultra SLI motherboard, outfitted with 4 GB of Kingston HyperX DDR3 RAM and a 3.0-GHz Intel Core 2 Quad processor.

This worthless 15-inch custom PCI-E cable did not work—so we replaced it.

We cooled our Palit GeForce GTX 280 graphics card with Danger Den's Tieton water block.

Seven fans circulate air within the desk—and 13 bright-blue neon lights blind the user at the desk.

Ejecting up from the desk surface is a Sony BDU-X10S Blu-ray drive.



PM TEST DRIVEN

American Muscle

IT'S A REAR-DRIVE, V8-POWERED REVOLUTION. BUT THIS REMIX OF 1960s SPEED IS MORE POLISHED, REFINED AND EFFICIENT. WE PUT THE LATEST PLAYERS TO THE TEST.

by **Larry Webster**

photographs by **Ture Lillegården**

There are few automotive genres more uniquely

American than the muscle car. Born, bred and built in the USA, these powerful machines of four decades ago packed a fiery V8 up front and drove torque to the rear wheels—a simple formula, precisely engineered for creating rebellious clouds of tire smoke. The bond that linked these cars together, besides the spine-crushing thrust, was their unrepentant machismo—quivering hood scoops, spoilers that scraped the stratosphere, and big, bold fender decals.

The muscle car heyday may have passed, but recently there's been a glorious resurgence. Ford introduced the retro-cool Mustang in 2005, firing the first salvo of the second muscle car war. Dodge fought back with the 2008 Challenger, and the 2010 Camaro is on the street and ready for the brawl. Now, the class is simply bulging with V8

bravado, including more progressive Cadillacs, Pontiacs and the undisputed king of muscle hill—the Ferrari-quashing, 638-hp Corvette ZR1.

Like the originals, today's cars offer a visceral thrill and a deep mechanical connection to the machinery. But these cars are not muscle-bound dinosaurs. They all handle, ride and glide through the daily commute just as confidently as they blister the quarter-mile. The

interiors are fitted with supportive seats, airbags and, yes, even Bluetooth connectivity and navigation systems. They use less fuel than ever too. Even the mighty Corvette ZR1 returns 20 mpg on the highway.

But to reach the new Corporate Average Fuel Economy (CAFE) standard of 35 mpg by 2020, the Detroit Three—and every other automaker—will need smaller, more efficient engines. In the years to come, the gasoline-fueled V8 just might become an endangered species.

What an irony that these incredible machines should land now, at a time when Detroit is fighting for survival. Is this the end of an era or a new golden age of muscle? Perhaps a bit of both. We gathered some of the most aggressive American iron

available and tested these cars at dragstrips in both Michigan and California. We logged hours ripping gears and connecting the curves on the most rewarding roads we could find. From behind the wheel of these machines, Detroit's troubles melt away as easily as a fresh set of tires.



Just like the old days—burning some rubber in the 2010 Camaro SS.





2010
CHEVROLET

CAMARO SS



The Camaro was the Mustang's very first rival—and now, its latest.

Eight long years have passed since the last-generation Camaro rolled off the assembly line. So is this new one worth that wait? Oh, yes. As intertwined as the Camaro nameplate is with Detroit, the 2010 model isn't a Motown native. It's an Aussie. The bones come from GM's Australia subsidiary, Holden. The folks down under covet V8s as much as Americans do. And thanks to those demanding roads in the outback, they know how to develop a supple rear-drive chassis. So this Chevy has something no Camaro before it has ever enjoyed—an independent multilink rear suspension. The Camaro SS is utterly unflappable. On midcorner bumps it stays planted and barely notices the ripples. The ride is firm, communicating the road texture through the steering wheel, yet it's never harsh. The engineers have found the right tuning to round off all the rough edges. The Corvette-derived 426-hp 6.2-liter V8 and Tremec six-speed manual produce quarter-mile sprints around 13 seconds flat. That, folks, is very brisk. Compared to the

the specs

BASE PRICE/AS TESTED	\$30,995/\$35,000 (est.)
POWERTRAIN	426 hp/420 lb-ft 6.2-liter V8, 6M
SUSPENSION (F/R)	Independent strut/multilink
BRAKES (F/R)	14.0-in. disc/14.4-in. disc
ACCELERATION (SEC)	
0-30 MPH	2.23
0-60 MPH	4.90
40-70 MPH	3.0
1/4-MILE	13.02 @ 111.4 mph
BRAKING (FT)	
30-0	26.6
60-0	107.8
EPA FUEL ECONOMY (MPG)	
CITY	16
HIGHWAY	24

Mustang and Challenger, the Camaro is the quickest pony on the field. The SS has nearly Porsche-level stopping power—huge Brembo discs stop the car from 60 mph in only 107.8 feet. The Camaro has this year's most striking wrapper too. The 1967 cues are certainly present, but all the shapes have been pulled forward into the 21st century. The interior continues the vintage theme, especially the optional gauge panel located in front of the shifter. The interior is devoid of wind noise, road impacts are merely subdued thumps, and unless you floor the throttle, the V8's music is muted. As much as we appreciate this gentility, is the Camaro a little too polished to be classified merely as a muscle car? Perhaps. ☹





The Mustang is fresh from a mild redesign. But every Mustang fan knows the powertrain. The 4.6-liter V8 now makes 315 hp. Okay, so, compared to the larger-displacement competition the Mustang seems, well, wimpy. But the key to the Ford's persona and performance is weight—or more precisely, lack thereof. The 3500-pound Mustang GT is about 400 pounds lighter than the Camaro SS or Challenger R/T. So the relatively modest power meant we blew past 60 mph in 5.6 seconds and ran through the quarter-mile in

13.9 seconds. The 4.6-liter sounds tough rumbling down the street, with an amplified version of the traditional V8 howl any motorhead kid will peg as a Mustang from three blocks away. The braking performance was rather unexpected: At 60 mph it stopped in 110.8 feet. That's only 3 feet longer than the Camaro. The Mustang is comparatively small too. So even with a solid rear axle, it feels light, tight and nimble. The Mustang encourages you to press it hard through twisty roads and isn't isolated

or hushed. There's a mechanical rawness that feels—old-school. The tradeoff is, of course, ride quality. While the Dodge and Chevy muffle big bumps and freeway imperfections, the Ford transmits every one of them to your backside. The Mustang is a rough-and-tumble street hustler—somewhat unrefined, but packing lots of attitude. ☒

the specs

BASE PRICE/AS TESTED	\$28,845/\$35,620
POWERTRAIN	315 hp/325 lb-ft 4.6-liter V8, 5M
SUSPENSION (F/R)	Independent strut/solid rear axle, coil springs
BRAKES (F/R)	12.4-in. disc/11.8-in. disc
ACCELERATION (SEC)	
0-30 MPH	2.29
0-60 MPH	5.62
40-70 MPH	3.81
1/4-MILE	13.93 @ 101.42 mph
BRAKING (FT)	
30-0	27.36
60-0	110.79
EPA FUEL ECONOMY (MPG)	
CITY	16
HIGHWAY	24

2010
FORD

**MUSTANG
GT**



how we tested :

This roundup of American muscle was a logistical puzzle that involved performance testing four cars in Detroit and two in California. Time constraints prevented us from performing fuel-economy or handling tests.

BASE PRICE/AS TESTED	\$30,945/\$37,410 (R/T)
POWERTRAIN	376 hp/410 lb-ft 5.7-liter V8, 6M
SUSPENSION (F/R)	Independent strut/independent coil spring
BRAKES (F/R)	13.6-in. disc/12.6-in. disc
ACCELERATION (SEC)	
0-30 MPH	2.56
0-60 MPH	6.39
40-70 MPH	4.44
1/4-MILE	14.44 @ 97.12 mph
BRAKING (FT)	
30-0	32.7
60-0	126.89
EPA FUEL ECONOMY (MPG)	
CITY	16
HIGHWAY	25

the specs

The Challenger R/T is more

retro—more like the original design—than either the new Camaro or Mustang. When a Challenger rumbles past, you notice the aggressively inset front grille, the trunk-spanning taillights and the taut greenhouse. It's a stunningly cool design. Underhood is the glorious Hemi V8 that displaces 5.7 liters in R/T trim and makes 376 hp. That's plenty to light

up the fat rear tires. The more expensive SRT8 packs 425 hp, the same as the legendary 1970 Hemi. But today's fuel-injected, computer-controlled Hemi has none of the sins of its cantankerous, carbureted precursor. Throttle response feels instantaneous. Coupled with the six-speed manual and pistol-grip-style shifter, the Challenger SRT8 clears 60 mph in 5 seconds and given enough blacktop, runs to 170 mph. That's fast, but the Challenger's Achilles' heel is its heft. Full of fuel, a V8 Challenger weighs around 2 tons. That's a lot of mass for

even the mighty Hemi to overcome. The Challenger feels big—it's only 2.4 inches shorter than its sedan sibling, the Charger—and a bit ponderous to whip through a snaky road. But the payoff is a resilient ride. That touch of compliance doesn't spoil the steering or the competent handling. Rather, the SRT8 bites crisply into corners. The Challenger offers a bit more room in the rear seats and trunk than its rivals. It's the practical ponycar. The R/T starts at \$30,945, but to keep up with the Camaro SS you have to upgrade to the \$42,645 SRT8. The good news? It's luxury-car loaded—so there's no need to sacrifice anything but your paycheck for that Hemi V8 rumble. ☒

DODGE

2009

CHALLENGER

R/T and SRT8



Pontiac G8 GXP

Chevrolet Corvette ZR1

2009

PONTIAC

G8 GXP

The Pontiac G8 is the Camaro's older brother.

The two cars share the same basic DNA—that Holden platform—but the Camaro's been through a more recent round of development. Yet the Pontiac G8 GXP simply brims with character. It's alive with V8 vibrations that gently rock the body at every prod of the throttle. This GXP, oddly, feels more like a Camaro than the actual Camaro. The Pontiac has the same 6.2-liter V8 as the Chevy but delivers about 10 hp less. No matter, the heavier G8 scorches to 60 mph in only 4.9 seconds. Just as in any proper muscle car, the V8 dominates your environment. So switch off the stability control, goose the throttle, and you can effortlessly drift around in a glorious, tire-shredding power slide. There's an eagerness to the G8 that the Camaro lacks, like it's at the end of a taut

leash, waiting for the release. Best of all, this visceral ride has four doors and fits four full-size adults; the trunk offers 17.5 cubic feet of space, enough for four weekend bags. In many respects, the Camaro is the better car. It's quieter, smoother, quicker and about 10 grand less expensive. It's best summed up like this: We respect the Camaro, but we lust for the G8 GXP. ✖

the specs

BASE PRICE	\$39,995
AS TESTED	\$40,690
POWERTRAIN	415 hp/415 lb-ft 6.2-liter V8, 6M
SUSPENSION (F/R)	Independent strut/multilink
BRAKES (F/R)	14.0-in. disc/12.8-in. disc
ACCELERATION (SEC)	
0-30 MPH	2.17
0-60 MPH	4.88
40-70 MPH	3.53
1/4-MILE	13.11 @ 108.93 mph
BRAKING (FT)	
30-0	27.67
60-0	111.01
EPA FUEL ECONOMY (MPG)	
CITY	14
HIGHWAY	20



2009 CHEVROLET CORVETTE ZR1

BASE PRICE/AS TESTED	\$106,520/\$116,520
POWERTRAIN	638 hp/604 lb-ft 6.2-liter V8, 6M
SUSPENSION (F/R)	Independent leaf spring/independent leaf spring
BRAKES (F/R)	15.5-in. disc/15.0-in. disc
ACCELERATION (SEC)	
0-30 MPH	1.87
0-60 MPH	3.70
40-70 MPH	2.15
1/4-MILE	11.50 @ 127.82 mph
BRAKING (FT)	
30-0	24.02
60-0	94.98
EPA FUEL ECONOMY (MPG)	
CITY	14
HIGHWAY	20

the specs



The price is shocking—

\$106,520—but in all performance categories, the Corvette ZR1 reigns supreme. It'll leap to 100 mph in just 7.8 seconds and pass 150 before your neighbor's minivan hits freeway speed. So how does this mega-Vette deliver such astonishing thrust? The V8, designated LS9 by GM, is fed by an Eaton supercharger to build an incredible 638 hp. Rest assured, electronic launch-control can automatically limit wheelspin and help you produce near-NHRA-quality launches. Should you get in over your head on a twisty back road, the stability control system will keep you from the ragged edge. A large part of the ZR1's excellence comes from lightweighting. The frame is aluminum; some body parts are carbon-fiber. So the ZR1 weighs just 3340 pounds, hundreds less than even more expensive exotics. Supercars can be punishing on the street, yet the ZR1 is planted, confidence-inspiring and nearly as smooth-riding as a plain-vanilla Vette. We're pining for another chance to slide behind the wheel. ✖



WINDOW BOX + BORDERS YOU
CAN MOW + GFCI TRIPPING

DIY Home

• The Dirty War

- GRIME BELONGS ANYWHERE BUT ON YOUR HOUSE'S SIDING OR SHOP FLOOR. HERE'S HOW TO PUT IT IN ITS PLACE.

BY LOGAN WARD

Inside

+ THE RIGHT
CLEANERS

+ PRESSURE-
WASHER TIPS

Spring cleaning around the home and shop may not be fun, exactly, but it is necessary. If there's any pleasure to be found in the work, it's in handling it efficiently. You already have a can-do attitude, otherwise you wouldn't be reading PM. And chances are you own a shop vacuum, and maybe a pressure washer. Here's the battle plan to win this dirty war.

Indoors

1 SAWDUST AND WORKSHOP CLUTTER

The chief culprit in workshop mess is sawdust. It's slippery underfoot and dangerous to breathe, so making short work of it should be your first priority. Begin by suiting up. Wear a dust mask and old clothes or, better yet, coveralls. Yeah, we know, it's

something out of your dad's generation—but keeping a pair of coveralls hanging in the shop will make it easier to keep clean. Store them there to keep grime out of the house and cut down on dusty laundry. Your dad was right about a few things.

Begin sawdust cleanup by working from the top of the shop down. Brush or vacuum off the tops of

hanging fluorescent shop lights. Speed the job along by buying an extra length or two of hose for your shop vacuum, enough to reach every corner of your shop. This makes post-project cleanup quick and easy; instead of having to roll the vacuum cleaner around the shop, you simply walk the hose around.

Once the floor and shelves are free of dust, turn your sights on bench-top clutter. Make sure every tool has a home by hanging hand tools on pegboard or storing them in boxes, but keep tools you're using in a plastic tote. That keeps them portable—and off the bench top. You can put them away when you're done.

2 GARAGE FLOOR GREASE AND OIL

You're better off dealing with spilled

lubricants and auto fluids while they're still liquid. They're a lot easier to remove in that form than after they've soaked into a concrete floor. Sprinkle on an absorbent powder—while everyone has heard of using kitty litter, you can also try dry cement or sawdust. Leave it for a few hours, then sweep up. If you really want to do a thorough cleanup, wet the area and sprinkle liquid dishwashing detergent, such as Cascade. Wait a few minutes. Pour boiling water on the area and scrub with a stiff-bristled brush. Then rinse.

3 BASEMENT MOLD AND MILDEW

A moldy basement is a sign that you've got a moisture problem. So don't bother cleaning until you've found the cause and completed foundation

repairs and drainage projects. After that's out of the way, cleaning is a piece of cake. Kill mold and mildew by mopping with a solution of a half-cup to 1 cup of chlorine bleach to 1 gallon of water. A squirt of nonammoniated dishwashing liquid will help lift the mold and mildew from the surface. Rinse, then pick up standing water with a shop vacuum. Blot up what remains with old towels. Evaporate remaining moisture by circulating the air with fans.

4 GROUT

Don't feel bad if you've got moldy bathroom grout and tile. It can happen even if you clean conscientiously. We have a home-brewed formula to handle it (though you shouldn't use it on colored grout). Make a paste of Bon Ami Polishing Cleanser and chlorine bleach diluted with water. Ironically, people buy Bon Ami because it doesn't contain bleach or harsh abrasives, yet it's these qualities that make the product an ideal foundation for a bleach-based poultice. Scrub the paste over the tiles with a soft brush. Let it dry, and rinse it using a brush and a pail of water. Wash off the hazy residue with a damp cloth, and wipe dry.

5 FIREPLACE BRICK

Sure, the brick inside a fireplace is meant to get dirty. On the other hand, if it's really grubby, a good scrubbing goes a long way to brightening the room that it's in. First put on a dust mask and sweep up ashes and cinders. If needed, use a spray bottle and apply a fine mist of water to keep the dust down. Don't apply so much water as to create a slurry. To remove smoke stains, mix a half-cup of trisodium phosphate (TSP) in a gallon of hot water, or use a commercial scouring powder that contains bleach. Use the spray bottle and wet the brickwork with water, so that it won't sponge up whichever cleaning agent you choose.

Now, scrub with a stiff-bristled plastic or natural-fiber brush. You may be tempted to use a wire brush to scrub off the deposits, but don't do it. The brush is likely to damage mortar. Rinse the surface with warm water and blot the crud that comes off with rags.

KNOW YOUR STUFF

Cleaning Toolkit



FOR BEST RESULTS, MATCH THE CLEANER TO THE JOB.

	KILL GERMS	DISSOLVE SOAP SCUM	REMOVE GREASE	ATTACK DIRT
WHAT TO USE	Chlorine-bleach-based cleaners	Acidic cleaners	Dish detergents, powdered or liquid alkaline cleaners, solvents	Powder or liquid alkaline cleaners, such as those that contain ammonia or trisodium phosphate
WHY	A University of Michigan study concluded that bleach kills bacteria by attacking their proteins. Bleach also breaks apart light-absorbing molecules, lightening dark-colored stains. Of course, chlorine can also attack dark-colored fabrics or surfaces, discoloring them.	Soap scum is an alkaline precipitate, a layer formed after the water has evaporated, leaving behind a thin layer of soap and mineral particles. Acid-based cleaners such as vinegar and CLR (calcium lime rust) attack soap scum's alkaline chemical bonds.	Detergents contain surfactants, additives that reduce water's surface tension and help it dissolve the chemical bonds of grease molecules. Alkaline cleaners, such as dish detergent, attack greasy and oily acidic deposits. Solvents loosen molecular bonds, allowing grease and oil to be blotted up.	Alkaline cleaners break up and suspend soil molecules in water, allowing dirt to be flushed or scrubbed from a surface.

Outdoors

6 BARBECUE GRILL GRATES

Few things are as unappetizing as starting a nice family cookout on a nasty-looking grill. So scrape off the big stuff with a putty knife, then spray the grates with a noncaustic oven cleaner. Seal them up in a plastic garbage bag and let them sit overnight. Scrub with a brass brush and rinse with a garden hose; then get on with the family feast.

7 ALUMINUM AND VINYL SIDING

Dirty siding: bad. Clean siding: good. If only this job were that simple. Begin by covering outside light fixtures or electrical outlets with plastic bags. We admit that this next part sounds odd, so bear with us. Minimize streaking by washing the siding from the bottom to the top. Otherwise, the streams of solution racing down will leave hard-to-remove streaks. Rinse the opposite way—from top to bottom. Yes, pros often do just the opposite, but if you don't do this for a living and don't have the equipment and experience to move very quickly, follow our advice. Don't overlook the bottom edge of lap siding, soffits or anywhere that dripping water can cause a buildup of dirt.

To clean aluminum siding, use trisodium phosphate (TSP) and warm water. Use a soft brush and don't scrub so vigorously that you remove the finish. For vinyl siding, gentle scrubbing with some warm water and a little dishwashing liquid should do the trick.

For mildew-covered siding, try a product like Jomax House Cleaner and Mildew Killer. It's added to a solution of warm water and bleach and applied with a garden sprayer. It can often remove dirt and mildew without scrubbing.

8 ASPHALT DRIVEWAY

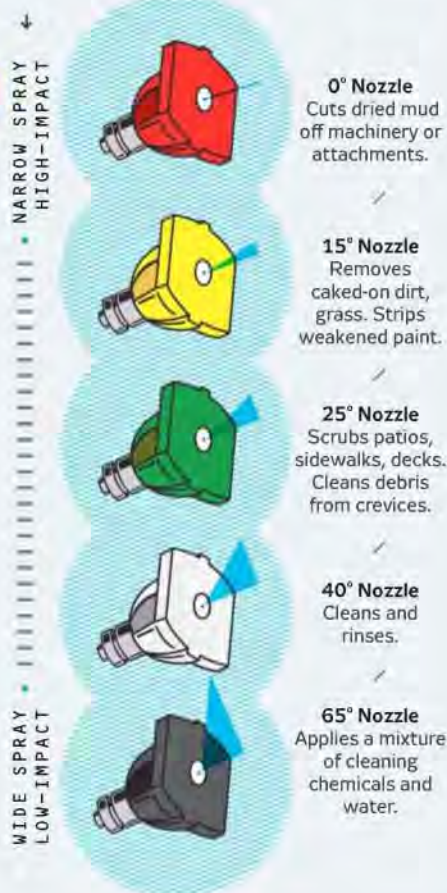
Do yourself a favor—tackle this job in the morning, while it's still cool. Use a broom and a leaf blower to remove

NOW YOU KNOW Nozzle Knowledge

For jobs around the house and yard, a pressure washer that operates at 1200 to 3000 psi is all you need. It's light-duty compared to those that operate at 4000 or higher, but it's still got enough power to do damage or cause injury. To use it correctly, first choose the right color-coded nozzle.

Do: Wear long pants, gloves and protective eyewear.
• Hold the nozzle 6 inches to 1 foot above the surface, or per the manufacturer's directions.

Don't: Spray against glass windows or doors or direct the spray upward when cleaning lap siding or sidewall shingles.
• Spray against electrical meters or network boxes for phone or cable service.



leaves and dirt. You've been waiting for a good use for those old recip saw blades you can't part with. Here's one: Use them to rake weeds and dirt out of cracks. Mix up some general household cleaner, such as Spic and Span, in a bucket with warm water, and scrub with a stiff-bristled broom. Rinse well with a garden hose. To keep out weeds, fill cracks with asphalt crack sealer.

9 FENCES AND DECKS

If you're well experienced with a pressure washer, you can carefully work your way over the surface with a 25-degree spray nozzle. For the inexperienced, scrubbing by hand is more likely to clean, not splinter, the wood.

Before you begin, thoroughly rinse nearby siding, trim and doors using a garden hose and spray nozzle. Wetting these surfaces prevents debris from

sticking to them. Next, mix 1 cup of TSP, 1 cup of liquid bleach and 1 gallon of warm water. Work a small area, then rinse before moving to the next, to ensure uniform cleaning.

10 LAWNMOWERS

If you've come this far, a little more cleaning won't kill you. Dried clippings block airflow above the mower's deck and hold moisture below. Brush them off the deck and from between the engine's cooling fins. Disconnect the lead from the spark plug, tip the mower on its side and scrape under the deck with a putty knife, and then rinse it with a garden hose. Tip the mower down; remove the engine shroud and vacuum the area clean with a shop vacuum. Remember to reattach the plug wire, though, or you'll never get that mower to start.

PM



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Sears

MENARDS

LOWE'S

Classics: Simple Do-It-Yourself Projects

Window Dressing

BUILD THESE QUICK, SIMPLE FLOWER BOXES AND WATCH THE FRONT OF YOUR HOUSE COME TO LIFE.

A lush window box spilling blooms can boost curb appeal in ways that a new paint job or reseeded lawn don't quite equal. I'm building six for my 15-year-old Cape—and after cranking up my power tools and making a big mound of sawdust, I was able to finish the first one in just one weekend.

Each box is essentially a 6- to 8-inch-deep trough with a slanted front, supported by two thick brackets and centered just shy of the window's width. Two brackets will support boxes less than 48 inches long, but longer boxes need a third, center bracket. I installed the boxes an inch beneath the sill of sliding and double-hung windows. On out-swinging casement and awning windows, I'd mount the box 6 to 8 inches below the sill, to leave clearance for the plants.

I'll repaint, one day. For now, I'm happy with the new splash of color.

by JOSEPH TRUINI
photographs by SARAH SHATZ



TECHNOLOGY

COMFORT

PERFORMANCE

INNOVATION

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1



4



7



2



5



8



3



6



9

Cutting

I crosscut the 1 x 8s to length using a miter saw. I cut the bottom, back and front of the window box to 36 inches long, and the two ends to 5¼ inches. The cleats, which mount to the house and support the box and braces, are 13 inches long. I used a table saw to rip the back to 6 inches wide, the bottom to 6¼ inches, and the two cleats to 2½ [1].

To create the box's slanted front, I adjusted the bevel angle of the table-saw blade to 15 degrees and bevel-ripped both edges of the front panel [2]. I adjusted the blade back to vertical, set the table saw's miter gauge to 15 degrees and made the angled cut to both window-box ends. I smoothed the cut edges with 80-grit sandpaper.

Next, I used a drafting implement called a French curve to draw the profile of the braces onto paper. I cut the paper along the curve, then traced the shape onto ¾-inch pine, and cut along my line with a saber saw [3]. I sanded the curved edges smooth using a drum sander in a drill press. You can also use the "nose" of a belt sander, or do it by hand.

Assembly

To add a decorative touch to the curved profiles, I routed a shallow cove into the edges of the braces. First, I clamped the router upside down, creating a make-shift router table. Then I carefully moved the curved edges of each brace and cleat along the bit [4].

Using an orbital finishing sander fitted with 120-grit sandpaper, I sanded each piece smooth. Using 1½-inch stainless-steel trim-head screws, I fastened the back to the bottom, and then attached the two ends, which were inset ½ inch [5]. (When driving a screw close to the end of a board, stay within 3 inches or so, and be sure to drill ⅛-inch-diameter screw-pilot holes to prevent the wood from splitting.) Using 1½-inch trim screws, I fastened the front panel to the bottom and to the angled ends [6].

I used exterior-grade wood putty to fill the screw holes in the front panel. Once the putty dried, I hand-sanded it flush with 120-grit paper. Using a ⅜-inch-diameter spade bit, I drilled six drainage holes through the bottom of the window box.

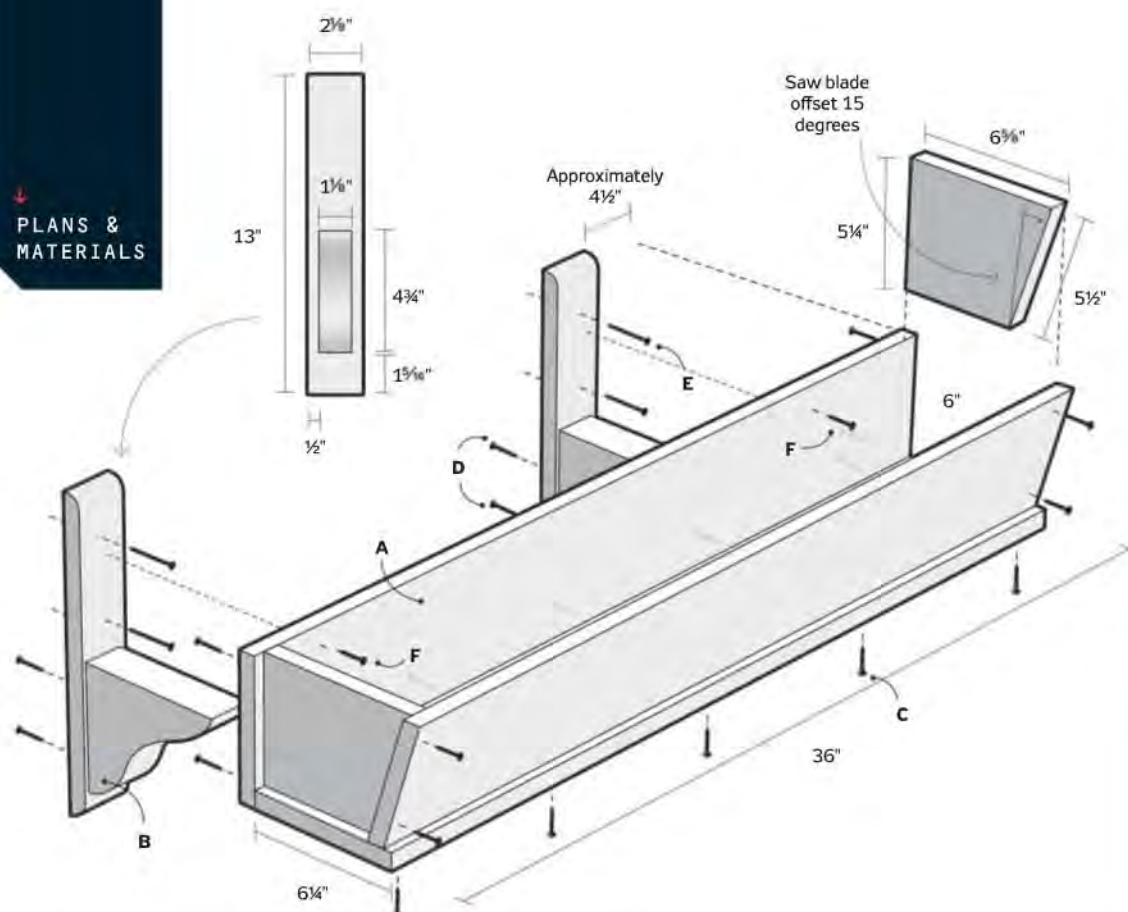
Installation

I attached the braces to the cleats with ⅝-inch stainless-steel trim-head screws driven through the back of the cleats [7]. The braces were centered on the 2½-inch-wide cleats, and placed 1½ inches from the bottom edges of the cleats. I then primed and painted.

To install, I drilled two counterbored screw-pilot holes through each cleat at 2½ inches and 5½ inches from the top edges. Holding a plumb level vertically against the first bracket, I used 3-inch decking screws to mount it 1 inch down from the windowsill and 5 inches in from the window-frame edge. With a 4-foot level across both brackets, I installed the second one just as I had the first [8].

I set the box in position, then centered it against the window and brackets. I drilled counterbored pilot holes through the upper back of the window box at each cleat. I then fastened the box to the cleats with 1¼-inch decking screws, driving near the top so I could remove the box without emptying it [9]. Then I filled the boxes with a potting-soil mix made specifically for containers.

PLANS & MATERIALS



Key	No.	Size and Description	Usage
A	2	8-foot 3/4-inch clear pine 1 x 8	Cut to make five sides of the box and two cleats
B	1	4-foot 3/4-inch clear pine 1 x 8	Cut and routed into two braces
C	18	1 1/2-inch steel trim-head screws	Attach the back, bottom, front and sides of the box
D	4	3/8-inch steel trim-head screws	Attach the braces to the cleats
E	4	3-inch decking screws	Attach the cleats to the house
F	2	1 1/4-inch decking screws	Attach the box to the cleats

Notes: A circular saw can be used in place of the miter saw and table saw mentioned in steps 1 and 2. If your house has vinyl, aluminum or fiber-cement siding, prevent damage by boring screw-pilot holes before mounting the cleats.



Stain Selection

I used two coats of exterior-grade primer and three coats of acrylic latex to paint my clear pine boxes, but I would have stained them if I had used red cedar or redwood. Both species accept stain

well and are naturally resistant to decay.

There are generally three tinted types of stains: semitransparent (1), semisolid (2) and solid (3). As you move to more solid stains, hue can change as pigment concentrations increase.

More pigment offers more protection, but it obscures the woodgrain. Clear and semitransparent stains allow the wood's grain to show. They're less protective, though, and require more frequent reapplication.

Homeowners Clinic

by Roy Berendsohn

Q + A

Mowable Borders

Q A house nearby has concrete curbs around its flower beds, and the owner can run the wheels of his mower along them—this cuts back on the time he spends with a string trimmer. Can I install these curbs?

A Yes, you can install a border that you can mow along, though the concrete variety you describe is best left to the pros. It requires tremendous labor to install, and an expensive rolling extruder that you'd either have to rent or buy through an industrial supplier or landscape supply company. The machine operator shovels concrete into the top chute and the curb machine forms the concrete into the shape that curves around the flower beds.

But setting that aside, you can consider a range of DIY options, from landscape timbers and pressure-treated lumber rated for ground contact to masonry, such as Pine Hall Brick. For long, straight runs, these bricks can be laid side by side horizontally, without mortar, but they should be mortared together if you want to curve them around flower beds. The brick can also be mortared vertically at the edge of a walkway or patio. This forms a graceful border to a patio or walk while producing a narrow mow strip. Also, take a look at Substiwood, a lawn edging made from concrete, recycled fly ash and shredded carpets. It's half the weight of concrete and can be readily sawed to length as well as nailed or screwed together.

You don't need much in the way of tools to undertake this project: a shovel, stake and strings plus basic masonry tools and a wheelbarrow if you go the brick-and-mortar route.

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KerbEdge pavers from Pine Hall Brick minimize mowing woes.

Rusty Gutter Hardware

The screws on my gutters and downspouts are rusty, as are some of the hanging straps. The gutters work fine, they just look crummy. Can I replace the hardware, but not the entire gutter?

You'll find the replacement hardware you need at any home center: gutter screws and ferrules (the tubes the screw runs through), hexhead screws with a white finish (known in the gutter trade as zip screws) and straps for the gutters and the downspouts. If you can't find the parts there, search under "gutter supply" on the Web. Finding the replacement parts is easy, but removing the rusty hardware may not be. Get a 3/4-inch nut-driver tool to remove hexhead screws and be prepared to clip off fasteners that are rusted in place.

Nuisance Trip

The GFCI outlet in the garage trips when I turn on my compound miter saw to do a little woodworking. The house is new, and all the wiring in it and the garage was done by professionals. The saw is also new. What could the problem be?

When a ground fault circuit interrupter (GFCI) trips, first check the device that's plugged into it—the outlet probably is telling you that something's wrong with your saw, perhaps a small short in the motor or at its trigger.

It's tempting to think the GFCI's to blame, but I doubt it. Yes, GFCI outlets do have a reputation for tripping easily—especially when confronted by large motor loads. That rap was deserved by the first generation of GFCI receptacles. But requirements instituted by UL in 2003 and 2006 have pretty much solved the problem. These days, when a GFCI is repeatedly tripped, it's likely the load.

A case in point is the time-honored beer fridge chugging away in the garage—and periodically trip-

ping the GFCI. Lots of homeowners and electricians assume this happens because the device can't handle the load of the fridge's compressor motor. But when GFCI manufacturer Pass & Seymour Legrand looked into this, it learned that the problem was that older appliances can leak current in the defrost cycle. A GFCI operates by comparing current headed toward the electrical load to the current returning on the neutral wire. If they are not equal, the device trips to prevent further current flow.

If the saw really is okay, investigate the electrical box where the GFCI is installed. Look for a loose splice on the neutral wire. Also, make sure excessive insulation wasn't stripped from the neutral—this could expose enough conductor to create current leakage where the stripped wire touches a bare grounding wire or the side of a metal box.

Summer Hot Water

We're happy with our old oil-fired boiler, which supplies our hot water, but we'd like to save energy and reduce oil use by not firing it this summer. Is an electric water heater the way to go?

Installing an electric water heater will reduce oil use, but it's not the optimal energy solution. "It's just much more energy-efficient to heat water with fuel than with electricity," says Thomas Butcher, a scientist who has run extensive studies on home heating at Brookhaven National Laboratory in Upton, N.Y. Heating with electricity is 100 percent efficient at the appliance, but only 37 percent efficient after accounting for inefficiencies to generate the electricity and transmit it. From an energy-saving standpoint, consider a new high-efficiency oil-fired boiler equipped to produce hot water. This also eliminates the need for the additional plumbing and wiring required for a water heater. **PM**

GOT A HOME-MAINTENANCE OR REPAIR PROBLEM? Ask Roy about it. Send your questions to pmhomeclinic@hearst.com or to Homeowners Clinic, Popular Mechanics, 300 W. 57th St., New York, NY 10019-5899. While we cannot answer questions individually, problems of general interest will be discussed in the column.

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Squeaky Brakes

DON'T PUT UP WITH THAT AWFUL CATERWAULING. MOST BRAKE NOISE IS EASY TO FIX. BY MIKE ALLEN

It's the first nice day of summer; you've taken the convertible out of winter storage and you're ready to hit the road. The stereo is cranking sweet guitar riffs as you cruise the beach, but for some reason the feedback on Wayne Kramer's ax (Motor City 5, for the uninitiated) starts to sound more like the drone string on Ravi Shankar's

sitar. And that's not good. Changing tracks, you find that same droning noise, and it isn't coming from your high-end stereo—in fact, it's your brakes. They are squealing. By the time you get back home, the noise has become so shrill it makes the dog hide under the porch and bark. The brakes seem to work just fine, but any

the
solution

This anaerobic adhesive will make the pad stick to the caliper, hopefully reducing squeal.

application of pedal immediately makes the noise louder. *Owww*, it's hurting your ears. Time to check the brakes.

It's Music, Man

Let's make one thing clear right up front: Sometimes your brakes will make noise. If you expect supreme silence, or expect your mechanic to make your brakes totally mute in every circumstance—that just may not be possible. Relax, don't worry. A squeaking brake can stop a vehicle as quickly as a quiet one.

So what makes the squeal, then? Modern brakes use a cast-iron disc squeezed between two brake pads lined with friction material. Under the right conditions, the disc, the pads and the caliper they're mounted in can start to vibrate—in exactly the same way a violin's string vibrates when stroked by

the horsehairs on the bow. The violin's pitch is controlled by the position of the violinist's finger on the string, not by how hard or fast the bow is stroked. Similarly, most brake squeals occur at a single discrete frequency. The speed of the vehicle and how hard you press down on the left pedal will only change the volume of noise, because the pitch is controlled by the stiffness and mass of the pad and disc.

Inadequate development at the manufacturer that leaves brake systems prone to noise can usually be overcome by a Saturday mechanic without totally re-engineering the caliper/mount/pad/disc system. We can try to damp out the noise, or simply change the resonant frequency of the whole arrangement until it stops singing in any audible frequency. Here's how.

Normal Pad Noises

Many brake pad compositions will make a swishing or grinding noise for

the first few stops in the morning until the pads warm up and drive off any moisture they've accumulated overnight. Ever notice a hissing or grinding noise on some rainy or dewy mornings? It's the pads sweeping a thin film of rust that's formed on the iron discs, and it's perfectly normal.

In the past, brake pad friction material relied heavily on asbestos. Unfortunately, asbestos tended to give asbestos workers and brake mechanics lung cancer, so the industry has almost completely changed over to less dangerous alternatives. Kevlar is one material that's seen a lot of use, but it tends to be dusty. Improved brake performance is more important nowadays because of increased safety requirements and equipment—and the extra road-hugging weight that comes along with these. That leads to the increased use of metallics and ceramics in the brake pad friction material. And this stuff can make the brakes hiss or even grind a little as you slow down. It's a small price to pay for increased performance. So all pad noise is fine, right? Hold up there, Sparky, there's one brake noise you need to pay attention to right away. Many brake pads have a small finger of spring steel that will scrape on the disc as the pad reaches its wear limit. This tells you that it's time to change pads for fresh, thicker ones before the friction material wears completely away, and you're trying to slow down on the metal backing plates. It's a sound not easily confused with brake squeal—it's more of a ripping-sheet-metal noise, not a single, high-pitched note.

Silence, Please

Okay, let's dig in and silence our brake noise. One fix is to simply change pads to a different type of friction material. It's usually hard to beat the original-equipment pads for a good compromise of pad life, noise, grip, dust creation and price, but changing to an aftermarket premium metallic or ceramic pad just might change the interaction that affects the resonant frequency of the pad and disc and, literally, change its tune.

Go into any auto parts store and

Brake Hardware Nitty-Gritty

1 This is one product we've tried that usually works to bond brake pads to the caliper and reduce or eliminate squeal.

2 This sheet-metal finger is just long enough to contact the disc when the pads are mostly worn out. The noise is calculated to make you replace the pads.

3 Here are two different compositions of brake pads. The one on the left is the stock pad installed by the factory, with a high concentration of organic fibers and brass particles. The aftermarket pad uses less brass and more ceramics for longer wear and improved braking.



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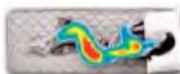
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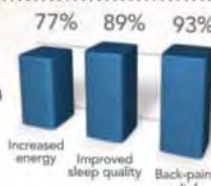
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you'll see a shelf full of potions and widgets claiming to cure squeaks. One class of products I'm leery of is simple aerosols that you spray onto the pad's friction material. I have no idea if they actually make the squeak go away, because I'm unwilling to try anything that changes the friction characteristics of the pad. Let's not forget, the first reason your brake system exists is, in fact, to make your car slow down. Anything that could reduce that system's effectiveness in any way is probably not a good idea.

Still got noise? Or still have plenty of pad material remaining and don't want to drop fifty or a hundred bucks on a fresh set? You may be able to decouple the piston acoustically from the pad by purchasing shims made of Teflon, which are intended to go between the pad and the caliper's hydraulic piston. I've tried those shims with middling success—sometimes they work and sometimes they don't. Warning: Some calipers will not have enough extra travel in the piston bore

to allow any shimming without making the brakes drag, at least with fresh, unworn pads.

You can achieve a similar decoupling without Teflon shims by simply coating the back face of the pad's backing plates with high-temp brake grease or even antiseize compound. Unlike shims, this tweak won't last forever, as water and road dirt will wash it away eventually.

We chose high-end ceramic-based pads for our brake job, hoping the different friction characteristics would

cure the squeal. Surprise, the new pads came out of the box fitted with Teflon-coated shims already installed.

Sticky Solution

Our favorite tweak for squeaks relies on a different principle: Instead of using shims or lubricants to decouple the pad from the caliper, stick the backing plate to the piston or caliper housing, effectively making its mass far larger. That will move the system's resonant frequency out of the range that squeals. A smear of Super Glue won't do it: You need something that will withstand the water, salt, filth and especially the heat that cars see in hard everyday use. How hot do brake systems get? I've seen brake discs glowing bright orange at the bottom of Pikes Peak, and flames shooting out of the brake drums of trucks descending Donner Pass. I've seen the brakes on my own race car visibly glow right after a few hot laps.

I've used several products over the years, but they're all basically anaerobic adhesives, applied as either a lipstick-style film or a toothpaste-style goo. The application of this product is simple: Remove and clean up the old pads, or use new pads. Clean the area on the piston and caliper where the pad backing plate touches. Apply the antisqueal adhesive, reinstall the pads and button up. These anaerobic products will stay gummy until you apply the brakes and squeeze out the oxygen. Then they stick like, well, glue.

Whenever you're installing any brake parts, be sure you remove any corrosion or road dirt from the mating parts—the brake pad or caliper housing needs to be able to slide in and out to compensate for wear. Clean up any sliding parts, which may require a wire brush or a file, until you can push the pads in and out with your bare hands. I prefer to replace any brake hardware (especially on drum brakes) that isn't in perfect condition—hey, it's cheap insurance. Apply a thin film of high-temp brake grease to any sliding surfaces. Obviously, avoid getting anything like grease or antiseize on the pad or disc, and clean any greasy handprints off the disc surface before you hang the wheel on too. **PM**



4 When installing new or old pads, sparingly coat all of the sliding surfaces on the pads, pins and hardware with high-temp brake grease. Use sparingly, and—duh—don't get any on the pads or discs.

5 File, sandpaper or grind any burrs, extra paint, rust or high spots off the pads, new or old, to be sure the pad will slide easily in and out as the brakes are applied and released.

6 Check out the raised areas—leftovers from the manufacturing process. We had to file down the steel backing plate on this aftermarket pad.



5





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Car Clinic

by Mike Allen

Q + A

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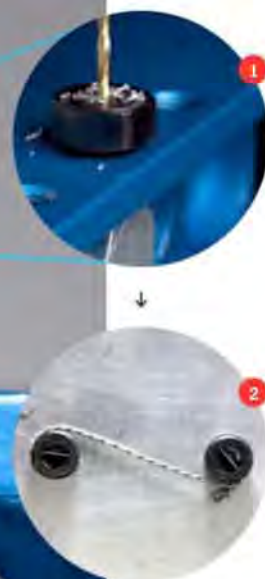
Staying Tight

Q I registered to take my sportbike to a track day so I could improve my street-riding skills, but the rules said I have to safety-wire a bunch of stuff, like the caliper bolts and the oil-drain plug. I don't even know what safety wiring is. Help!

A Safety wiring was developed for the aircraft industry, to prevent critical fasteners from loosening in midflight, which might ruin a perfectly good vacation, no? Thin stainless-steel wire is used to tie bolt heads and other fasteners to each other to prevent them from unscrewing themselves. I use this technique all the time on racing cars and motorcycles, because the vibration can eventually overpower even a properly torqued bolt. The process also ensures that everything has been assembled to its final torque spec, because you can simply go over the vehicle with a checklist and visually verify the presence of the safety wire without having to get out a

socket or wrench and trying to tighten every fastener. The hardest part of installing safety wire is cross-drilling the bolt heads. That tiny $\frac{1}{16}$ -inch drill bit snaps easily, usually just as the bit is exiting the far side of the bolt. This will not only ruin the drill bit, but potentially an expensive, high-quality bolt too—if you can't get the bit loose. I use a really neat drilling fixture from Graham Tool (grahamtool.com) and a cheap drill press, which makes the procedure easy. Clamp the bolt head to the fixture and clamp the fixture to the drill press table. A careful guy could do it with a bench vise and a hand drill, but skip the coffee that morning to keep your hand steady.

Install the bolt and torque it properly. If the hole doesn't line up correctly, you may have to drill a second hole, or swap the bolt with a different one. I generally use 0.032-inch aircraft stainless lock wire, which you can get at most speed shops or aircraft supply houses. Iron "mechanics wire" won't do. A handy item if you're doing a lot of safety wiring is special safety-wire pliers used to cut, clamp and twist the wire. Lone fasteners that don't have a nearby partner may require that you drill a hole in a nearby bracket, or add some other type of stationary point to thread the wire through.



How to Install Safety Wire

1. Start safety wiring by cross-drilling, or buy cross-drilled hardware. This fixture uses a collet to hold the bolt head steady and guide the drill.
2. There are special safety-wire pliers for installing the stuff, but you can do it with some small locking pliers. Wrap and twist the wire from one bolt to the next so the bolt heads can't come undone without removing the wire.

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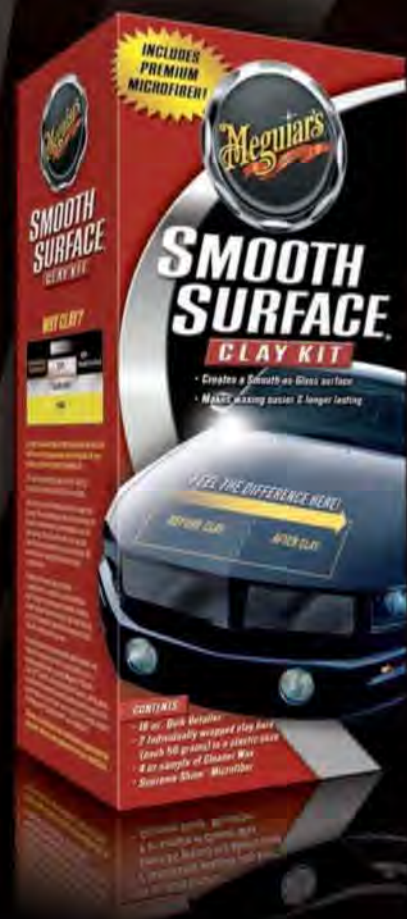
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Used or Used Up?

Is using a secondhand O₂ sensor in my car okay? Could I use an old one that I got from a boneyard and, if so, how much would it cost? I've been told that new sensors could run at least \$250 to \$300, including installation.

I'll never reinstall a used oxygen sensor from a different vehicle—or try to clean one and reuse it. A poorly running engine can damage a sensor permanently, and a few months of storage in a damp, muddy junkyard won't do it much good, either. Older oxygen sensors get lazy, and take longer to swing up and down in response to changes in the oxygen content in the exhaust stream. Are you willing to bet that junkyard sensor is any better than the one you're replacing? There's no way to test them except in a running engine.

I could give you a better idea of the price of a new sensor if you had bothered to mention the make, year, model and engine of your car. However, I can find new oxygen sensors for most vehicles for \$30 to \$40

each. You may have as few as one or as many as four in your car. The labor to change all four of them shouldn't be more than an hour. So, replacing all four might close in on \$250, depending on your specific vehicle. That sounds a lot cheaper in both the near and long term than your used-oxygen-sensor scenario.

Up in Smoke

My son was driving near our home and said his car suddenly lost heat and started to smoke. When I got it apart the heater-hose fitting going into the block was broken off.

I replaced the fitting and the hose, and filled the system with water to do a pressure test. I could hear a hissing sound but couldn't pinpoint where it was coming from. There's no antifreeze in the oil, but the engine won't turn over. Do you think the engine is locked up? Yes, I do. D'oh!

I was strongly tempted to leave it at that four-word reply, but I'll take this opportunity to point out that your failure scenario is fairly typical—

■ YOU NEED THIS

Calipers That Do Math

I've got three different sets of calipers in my toolbox. There's an old-fashioned set of vernier calipers in metric and inch spec. The DC-1 from Park Tool (parktool.com) is going to replace them all. It's a fairly ordinary set of digital calipers, switching instantly from inches to millimeters at the touch of a button, and it's accurate to a hundredth of a millimeter. Press the scale button a third time and it reads in fractions of an inch, down to 128th of an inch. This is a major timesaver, especially when you're working on one of the original "hybrid" cars—the ones that were made in the late '70s and '80s with a mishmash of metric and inch-size fasteners.



you've got a blown engine. Here's what happened.

It started with a catastrophic loss of coolant—which must have sprayed all over the underhood area, creating a lot of steam and that unmistakable hot-Log-Cabin-syrup-in-a-Turkish-bath smell. Shame on your son for not stopping and checking. Next symptom is the loss of heat, caused by the level of coolant dropping below the point where the water pump could circulate it through the heater core. The smoke is from oil working its way up the cylinder walls past the melting piston rings, scuffed piston skirts and scored cylinder walls to burn in the combustion chambers. That hissing sound is the compressed air you're pumping into the radiator. It's escaping from blown head gasket(s), because the cylinder head or heads are warped. Now, air is escaping from many, many places—which is why you can't pinpoint it. The starter won't turn it over because the pistons have welded themselves to the cylinder walls.

Bottom line: That engine is toast, and probably not worth rebuilding. It'll need new pistons and rings, and new or rebuilt heads. The block will need to be bored and milled too. My suggestion: Get a used engine from a salvage yard. **PM**

GOT A CAR PROBLEM? Ask Mike about it. Send your questions to pmautoclinic@hearst.com or to Car Clinic, Popular Mechanics, 300 W. 57th St., New York, NY 10019-5899. While we cannot answer questions individually, problems of general interest will be discussed in the column.

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Whether it's the all-new 2009 H3T pickup, the versatile midsize H3, or the legendary and supremely capable H2, owning a **HUMMER** affords you the ultimate freedom to go just about anywhere and do just about anything. While allowing you to reconnect with all those things that make you feel like yourself again.

H2

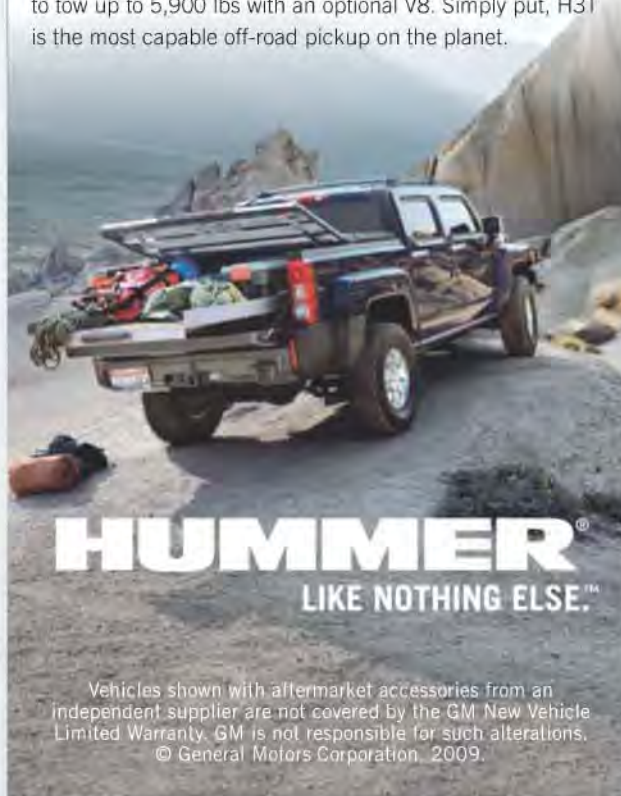
H2 offers a powerful 6.2L E85 FlexFuel V8 engine that generates 393 hp and 415 lb-ft of torque – making it capable of handling almost any off-road situation. And the H2 SUT gives you all the same capability with a midgate that folds down to create a six-foot bed, extending the possibilities of what you can do with your H2.

H3

H3 is the perfect combination of capability and efficiency in a mid-size SUV, making it fully comfortable both on-road and off. What's more, the H3 Alpha features a 5.3L V8 engine with 300 well-domesticated horses, enabling you to tow up to 6,000 lbs.

H3T

As the first true HUMMER pickup, the 2009 H3T is capability and versatility in a supremely attractive package, offering a 5-foot bed with 33.5 cubic feet of cargo space, best-in-class approach and departure angles, and the ability to tow up to 5,900 lbs with an optional V8. Simply put, H3T is the most capable off-road pickup on the planet.



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ROAMING KINDLE + VISTA STARTUP
CAMCORDER PHOTOGRAPHY

DIY Tech

The Great Text Rip-Off

Q My cellphone's text message bill seems to get higher every month. Is there any way of saving money on my texts?

A At roughly 20 cents a pop, text messages are expensive. But it takes a bit of perspective to realize just how pricey they really are.

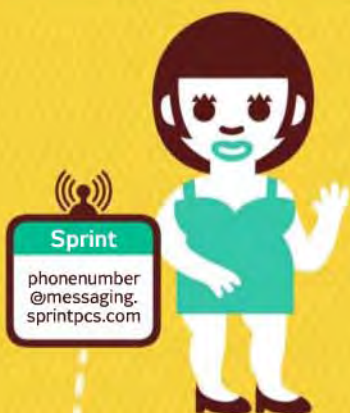
Short-message-service messages (that's the official name for text messages, often abbreviated to SMS) have a maximum of 160 bytes of data. Unless you purchase a bulk text-message package (which can cost as much as \$20 per month), the 20 cents-per-message rate adds up to \$1310.72 per megabyte. This is double the cost three years ago and, quite literally, astronomical: A space scientist at the University of Leicester in the U.K. did the math and discovered that this is several times as much as it costs to transmit data from the Hubble space telescope back to

Earth. And most of this cost is pure profit for the phone companies, who are able to deliver text messages for nearly nothing by piggybacking them on other transmissions.

Thankfully, there are ways to bring your bill down to earth. The key is to use what are known as SMS gateways. These are backdoors that transform other (usually less expensive) types of communications, such as e-mail and instant messages, into text messages. The upshot: You can send all the texts you want without paying for the privilege.

All major mobile-phone carriers have e-mail addresses that feed into your SMS inbox (see our diagram for specific addresses). If you have a smartphone and an all-you-can-eat data plan, you can use your phone's e-mail client to send as many texts as you want for no additional cost. Of course, this method has its limitations: In order to determine what

Instead of paying for text messages, send your note using e-mail or IM. Your target's e-mail address depends on his mobile provider.



address to send your message to, you first need to know what cellular provider your friends have. I suggest asking your most-texted contacts who their providers are. With that information, you can program the proper e-mail address next to their names in your phone's address book.

Easier yet: Send your text message over AOL Instant Messenger (versions of which exist for most mobile phones). Instead of sending your message to a screen name, send it to "+1" followed by the area code and phone number. So if your friend's number is 212-555-5555, sending an IM to "+12125555555" will ensure it pops up on his cellphone screen. If your phone has Web access, you can also send free texts through sites such as txtdrop.com.

Of course, you still have to pay to receive text messages from other people. If somebody replies to a text message that you sent as an IM or e-mail,

his reply will come to you in the format you initially sent it in, and reading it won't cost you a thing. You can cut your bill even further by asking your most-texted friends to program your e-mail address into their address books. Even if they insist on using SMS, sending a text message to your e-mail address will cause it to appear in your e-mail inbox. And as long as you have an e-mail program on your phone, it will be just as easy to retrieve.

Amazon Vacation

I recently purchased the Amazon Kindle 2 e-book reader, and I am planning an overseas trip. Can my Kindle download new books while I'm abroad?

One of the best features of the Amazon Kindle e-book reader is its built-in cellular antenna, which allows you to surf the Web and download e-books without relying on a PC middleman.

And, thanks to Amazon's partnership with Sprint, the network access is completely free.

However, because Sprint is an American cellular provider, this arrangement is useless once you leave U.S. soil—the Kindle currently has no roaming options. Even if the Kindle did have the ability to roam, it wouldn't work very often—the Kindle has an EVDO radio, which is incompatible with the GSM wireless networks that are used in most of the world. In order for it to be useful as a truly international device, it would need a slot for a SIM card, which would allow it to log onto these GSM networks. While Amazon has given no indication that it is planning to include this feature in future versions of the Kindle, we wouldn't be surprised to see it before long.

Of course, you can still download e-books (as well as other content such as magazines and daily newspapers) to your Kindle while abroad. You just need to do it through your laptop by using Amazon's Web-based Kindle store. Once downloaded, these books can be easily transferred to your Kindle through a USB cord.

Dual Shooting

My Canon camcorder can take large, multi-megapixel still photographs. But if I'm shooting video at the same time, it can only produce 2-megapixel shots. Why is this?

Camcorders typically have a single image sensor. Take the Canon Vixia HF11 high-definition camcorder. When used as a still camera, it can produce 3.1-megapixel photos. But shoot video at the same time and the resolution is knocked down to 2 megapixels. The reason: The camcorder, when asked to tackle both tasks simultaneously, doesn't actually take a separate photo. Instead, it just slices a frame out of the video you are already shooting. Like all 1080p or 1080i high-definition camcorders,

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it shoots video at a maximum resolution of 1920-horizontal-by-1080-vertical pixels. Multiply those two dimensions together and you get 2,073,600—or just over 2 million total pixels. To put it another way: Any given frame from a 1080p high-definition movie is about equivalent to a 2-megapixel still photo.

Altered Boots

When I start my Vista PC, it automatically loads a lot of unnecessary programs. What's the easiest way to change which programs load at startup?

In general, it's a good idea to reduce the number of programs that your computer automatically loads at startup to the bare minimum. While auto-loading a frequently used program can be convenient, it adds seconds to your computer's startup time. My suggestion: Set your computer so the only applications that load automatically are your antivirus and antispyware programs, and anything that seems like a

tech term

Dynamic Composable Computing

Modern mobile devices are plagued by tiny displays and cramped keyboards. A solution being championed by Intel: Dynamic Composable Computing. The idea: Mobile phones and pocket PCs will wirelessly connect with nearby peripherals, allowing you to use them with keyboards and TVs, and even to borrow processing power from nearby PCs. It's one more step toward a future where our assorted technology is constantly communicating with each other, and our primary PC can be carried in our pocket.

critical system function (if you're not sure what a program does, Google it). You'll be shocked at how much faster your PC starts up.

Windows stores its list of startup programs and system applications in two places. The first can be accessed by typing: "C:\ProgramData\Microsoft\Windows\Start Menu\Programs\Startup" into the address bar of a Web browser or Windows folder. (This folder can also be accessed by clicking the Start button on the bottom of the screen and then clicking All Program and Startup.) To add a program, right-

click on an application's .exe file (this will be the icon you click to load the program), and select "Create Shortcut." Once the shortcut is created, drag it into the Startup folder. Removing startup programs is just as easy: Just delete shortcuts from the folder by dragging them into the recycle bin. To cull system-level startup programs, click the Start button, then type "msconfig" into the Start Search bar that pops up. This will bring up a System Configuration window. Clicking on the Startup tab will allow you to select or unselect startup programs.

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Apollo 11: The Untold Story (CONTINUED FROM PAGE 83)

translate back down to the surface, I could find out where the lunar module was. They were off another 5 miles from anything that we had.

• **Gavin:** In my mind, the riskiest unknown in the whole mission was the takeoff. When the astronaut pressed the button, a whole bunch of things had to happen. The explosive bolts connecting the two stages had to fire. And then the ascent engine had to be ignited to lift the ascent stage off. And somehow as it left the descent stage, the exhaust from the ascent engine had to go somewhere.

• **Owen Garriott, astronaut (CAPCOM), Maroon Team, Mission Control:** The engine on the lunar module has one chance, which must be perfect. People had spent a lot of time back at Grumman doing the design, preparation and testing for it.

• **Aldrin:** As I got down on the floor to sleep [the night before], I could see the broken head of a circuit breaker—the one that's got to be in to get electricity to turn the ascent engine on. Since it was on my side, obviously I would have to take the blame for my backpack knocking against things clumsily and breaking it off.

• **Loden:** That circuit breaker allowed the lunar guidance system to start the engine automatically—but there was another way to start the engine. We had redundancy. They would have had to hit a pushbutton manually at T minus zero.

• **Aldrin:** It looked as though there was enough left to push [the breaker] in. When the time came, I just said I was going to push it in with a pen.

• **Glynn Lunney, flight director (FLIGHT), Black Team, Mission Control:** Once the ascent stage is lit, the vehicle really jumps off the moon.

• **Aldrin:** It was not a gradual liftoff. It was a sudden departure—but without any of the forces that go along with rapid acceleration. Looking out the window, everything was getting smaller so fast that [we didn't really notice] the craft going through a gradual pitch forward.

In order to dock with the command/service module, the lunar module executed a series of burns, bringing the two craft together.

• **Blair-Smith:** The lunar orbit rendezvous wasn't that different from what the Geminis did in Earth orbit. But it was more nerve-wracking because if it didn't work, where everybody would be left was not going to be very good for them.

• **Gavin:** It was an emotional worry that people had. But those of us who were directly involved with the details were always very confident—otherwise we wouldn't have said we were ready to go.

THE RETURN TRIP

Two hours after the vehicles docked, the command/service module jettisoned the lunar module. The main engine then fired to send Apollo 11 on a trajectory for Earth.

• **McCandless:** Lunar orbit insertion was critical to a mission's success, but it was less critical to the survival of the crew than the trans-Earth injection burn. If you couldn't get out of lunar orbit you had a real problem.

• **Alan Kehlet, Apollo chief project engineer, North American Rockwell:** Some guy ran an analysis of all the critical events that had to take place and came to the conclusion we didn't have enough reliability, that it would never work. But we discarded it.

• **McCandless:** It pretty well boiled down to the SPS—service propulsion system—engine; that had redundant valves, circuits, actuators, switches. Everything was singlefold redundant.

• **Kehlet:** [Apollo 11's command module] had the best-performing engine and equipment. We didn't have a lot to spare, mainly because of cost, so the idea was that you robbed the next vehicle to go to the Cape for equipment you needed. I made sure that 107, the spacecraft on mission Apollo 11, got separated from all that.

• **Loden:** Of course, the lunar module stayed in orbit around the moon and we watched it die. It was like losing a good friend. But it performed its job tremendously well, and we configured certain systems in ways that,

after jettison, would give us insight as to how long it could last.

• **Carlton:** The name of the game for us flight controllers was to try to learn the outer limits of all of our equipment. Some people called it playing with it, but it was serious business. We wrung that thing out.

• **Gavin:** And then the rest of the mission was a matter of waiting until orbital mechanics brought everybody back to Earth.

JULY 24, 1969—SPLASHDOWN

After a three-day coast toward home, the command module separated from the service module and entered Earth's atmosphere.

• **Reed:** Coming back from the moon, you're coming in a lot hotter than ever before—at 36,000 feet per second. In Earth orbit, it's 25,000.

• **Kraft:** Because the velocity is so high, if you tried to come in directly, the heat-shield requirements would be too great. So what we did was get them into the atmosphere, skip it out to kill off some of the velocity, and then bring it back in again. That made the total heat pulse on the heat shield of the spacecraft considerably lower.

• **Windler:** It was [still] so hot that the heat shield was abrading and there was a big ionization shield all around them. It prevents communication until [the command module] slows down enough for that to stop.

• **Clancy Hatleberg, pararescue man, underwater demolition team 11, U.S. Navy:** The USS *Hornet* had steamed all night long with the helicopters, the two recovery teams and myself. The sea states were the highest we had ever encountered in any of the simulated exercises that we had performed in preparation.

• **Aldrin:** There's a big solidness to the force as you're coming into the atmosphere, and it's gradually decelerating the spacecraft. You could sense a g before it really showed up on the indicator, and by then it's pretty firm. It's pushing you toward the back of the couch and down.

• **Hatleberg:** I was in helicopter 66. I remember looking out of the cockpit, and I could see we were on the outskirts of a storm: The sun was rising up above the clouds, but it was dark down below. It was sort of like being caught between night and day. Then all of a sudden I saw this streak coming through the upper atmosphere. It looked like a meteor. And then three chutes opened up.

• **Aldrin:** It was a moderate jolt. Then there's a bit of a sway once you're hanging there. When you're actually on the water, there's a firmness that didn't exist before; there's an intellectual knowledge of being supported by something.

• **Hatleberg:** Once everything was in place, I jumped into the raft and they lowered the decontamination bottles and the [biological isolation garments] and the mitt that I used to wash down the command module and the astronauts. I gave a thumbs-up to the helicopter when the decontamination was complete and 66 came into position and lowered a net.

• **Liebergot:** We didn't consider them recovered until we saw the astronauts removed from the command module in the ocean by helicopter and step out on the deck of the aircraft carrier. Only then did we celebrate. We were steely-eyed missilemen. That was our deal.

• **McCandless:** The whole mission was about as close to perfect as you can get with three human beings onboard and an unexplored terrain.

• **George Mueller, associate administrator for manned spaceflight, NASA:** Looking back, it was really a whole lot of people working on the same problem, making sure the piece that they had would do what it was supposed to do when it was supposed to do it—10 million pieces and 400,000 people. And every one of those people was very, very dedicated.

• **Liebergot:** We were young, and we were fearless and, after all, nobody had ever told us young engineers that we couldn't successfully land humans on another planet. So we did it. **PM**

Along with NASA historians and archivists, PM would like to thank the following Apollo 11 veterans, whose perspectives were invaluable to our research: Aaron Cohen, Chuck Deiterich, Paul Donnelly, Charlie Dumis, Jackie Smith and Tom Sylvester. For a more comprehensive version of this oral history, go to popularmechanics.com/apollo11turns40.

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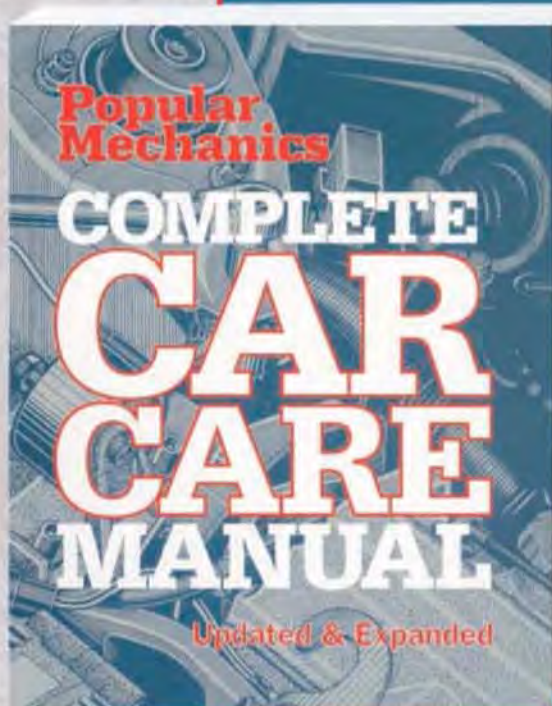
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1. Loop Knives

A cracked hoof is a messy sight: all dirt, dried blood and chipped horn. McKinlay starts by trimming away the grime with a hooked blade. "A nice, tight little hook can get in there and expose the problem," he says.

2. Die Grinder

Equipped with a crosscut bur attachment, the handy Makita GE0600 allows McKinlay to further tidy the damaged area. "It helps your glue to stick," he says. "The best adhesion comes when you get a smooth, clean surface."

3. Drill

Using a high-speed—up to 30,000 rpm—handheld Black & Decker RTX drill outfitted with a No. 62 cobalt bit, McKinlay precisely bores two sets of minuscule guide holes in the damaged hoof. Stainless-steel sutures slide through these and are twisted to pull the crack together.

4. Glue

With the crack sutured, a cast of glue holds everything in place and protects the wounded foot. McKinlay uses a methacrylate adhesive, which takes only about 5 minutes to dry. "I used to use a 3M glue, but it took 5 hours to set," he says.

5. Yasha Horseshoes

The Air Max of horseshoes, McKinlay's Yasha resembles standard hoofwear. But between metal and hoof is a cushioning dual layer of polyurethane that practically eliminates crack-causing concussion. The design just might revolutionize horseshoeing.



Farriers have been shoeing horses for two thousand years, but none have done the job quite like Ian McKinlay. Using a repair method devised 40 years ago by his father, a relatively simple set of tools and his own revolutionary Yasha shoe, the 51-year-old routinely treats horses afflicted by hoof cracks—including last year's Triple Crown hopeful Big Brown, who was diagnosed with a quarter crack on his front left hoof after the May '08 Preakness Stakes. Though the thoroughbred failed to capture the third jewel in the crown, McKinlay's fix held—and allowed him to test his shoe at one of horse racing's grandest venues. "I hate to admit it," McKinlay says, "but Big Brown was part of our research and development." —JOE R. HASLER



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